First Edition, November 1901 ; *reprinted, May* 1903

DEDICATED

TO THE

YOUNG PEOPLE IN ALL

ENGLISH-SPEAKING SCHOOLS.

(*To be read after the book has been read through.*)

THREE years ago I published a book intended more especially to enable the younger generation of readers to appreciate the wonderful advances in Science and the Arts during the Nineteenth Century.

In order to reduce the size of the work, and to render it more interesting, I limited the subjects treated in it to those inventions and discoveries which were altogether new in principle or in practical use—not mere improvements or advances on what had been known or done in preceding centuries.

This book was widely read, and my publishers suggested that the more interesting portions of it would make an attractive and useful Reading-Book for use in schools throughout the English-speaking world.

The present volume carries out this idea, and the copious illustrations will, I hope, render it both intelligible and interesting to you, my young readers and friends. It will, I hope, serve to bring vividly before you that older world in which your grandfathers and grandmothers spent their youth, and will thus enable you better to understand the enormous changes that the Nineteenth Century has witnessed.

In the original work I also pointed out, in some detail, that the great advances described therein have not been unmixed blessings to mankind, but have been accompanied by many evils, often intensifying those

that existed before. This is not, however, in any way the fault of the discoveries themselves, but is due to the fact that advances in our social system and our laws have not kept pace with material and intellectual advances.

This part of my subject is not, however, suitable for young readers; but it is mentioned here in order that, later on, such of you as are interested in these less popular subjects, may know that they are fully treated in the larger work.

In conclusion, I would impress upon you all that you are entering upon life in a world of vaster possibilities for both good and evil, than were open to any previous generation. Whether the good or the evil shall preponderate will depend largely upon yourselves. If, as preceding generations have done, you use the great powers which science has given you solely for your personal advantage, caring nothing for the well-being of those who may be less clever or less fortunate than yourselves, the world will surely grow worse than it is now. But if you determine, in your character as citizens of a self-governing community, that these wonders of scientific discovery and all this labour-saving machinery shall be so utilised as to benefit all alike, and thus render it possible, at the very least, for every worker to secure not only all the necessaries and comforts of life, but leisure to enjoy the wonders of nature and art now open to all, followed by a restful and happy old age, then you will be the originators of a work of social advance and regeneration in the Twentieth Century which will far surpass all the material and intellectual progress of the Nineteenth.

With all good wishes for your success in this great work, I subscribe myself,—Your sincere friend,

ALFRED R. WALLACE.

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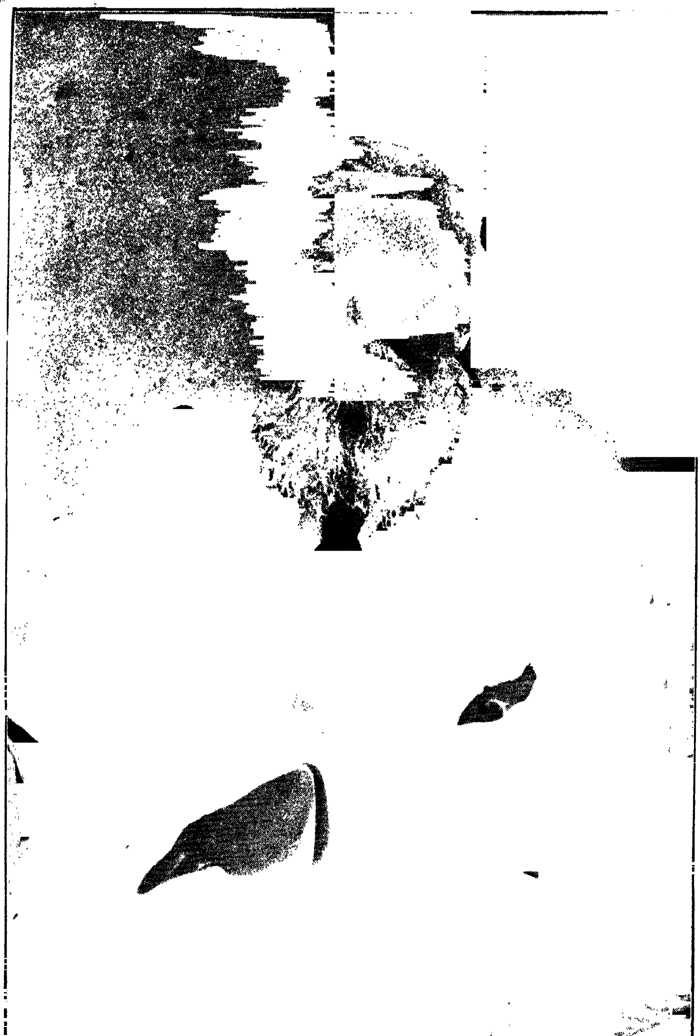
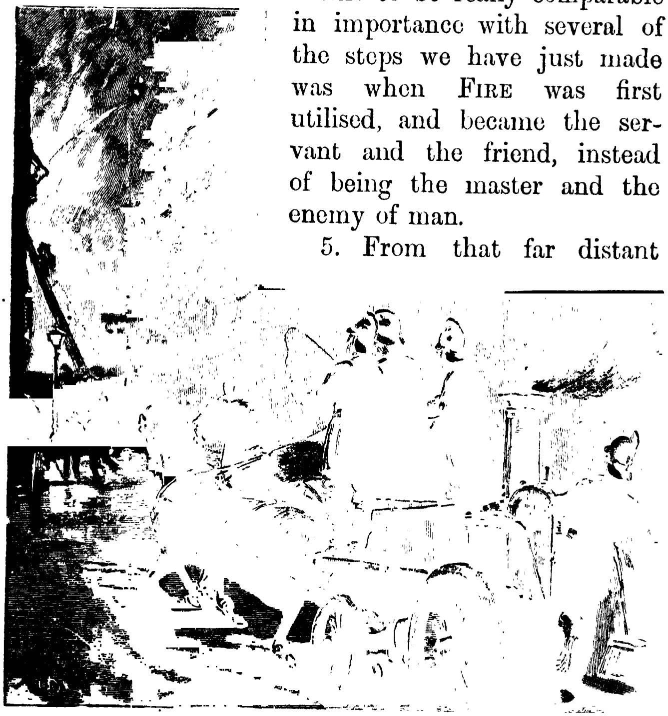


Alfred R. Wallace

with the whole historical period—perhaps even with the whole period that has elapsed since the Stone Age.

4. Looking back through the long dark vista of human progress, the one step in material advance that seems to be really comparable in importance with several of the steps we have just made was when FIRE was first utilised, and became the servant and the friend, instead of being the master and the enemy of man.

5. From that far distant



3. FIRE AS FOE

epoch even down to our day, fire, in various forms and in ever-widening spheres of action, has not only ministered to the necessities and the enjoyments of man, but has been the greatest, the essential factor, in that continuous increase of his power over nature, which has undoubtedly been a chief means of the

growth of his intellect and a necessary condition of what we term civilisation.

6. Without fire, there would have been neither a bronze nor an iron age, and without these there could have been no effective tools or weapons, with all the long succession of mechanical discoveries and refinements that depended upon them.

7. Without fire, there could be no rudiment even of chemistry, and all that has arisen out of it.

8. Without fire, much of the earth's surface would be uninhabitable by man, and much of what is now wholesome food would be useless to him.

9. Without fire, he must always have remained ignorant of the larger part of the world of matter and of its mysterious forces. He might have lived in the warmer parts of the earth in a savage or even in a partially civilised condition, but he could never have risen to the full dignity of intellectual man, the interpreter and master of the forces of nature.

10. Having thus briefly stated the subject of the present volume, and how it is proposed to treat it, we will proceed to sketch in outline those great advances in science and the arts which are the glory of the past century. In the course of our survey we shall find that the more important of these are not mere improvements upon, or extensions of, anything that had been done before, but that they are entirely new departures, arising out of our increasing knowledge of and command over the forces of the universe. Many of these advances have led to results of the most startling kind, giving us such marvellous powers as would have been incredible to our greatest men of science a hundred years ago. We begin with the simplest of these advances, those which have given us increased facilities for locomotion.

LESSON 2

4 WOODHOUSE TOWER, CALEDONIAN RAILWAY

MODES OF TRAVELLING

"Put forth your force, my iron horse, with limbs that never tire!
The best of oil shall feed your joints, and the best of coal your fire;
Like a train of ghosts, the telegraph posts go wildly trooping by
While one by one the milestones run, and off behind us fly!
Dash along, crash along, sixty miles an hour!
Right through old England flee!
For I am bound to see my love,
Far away in the North Countrie."

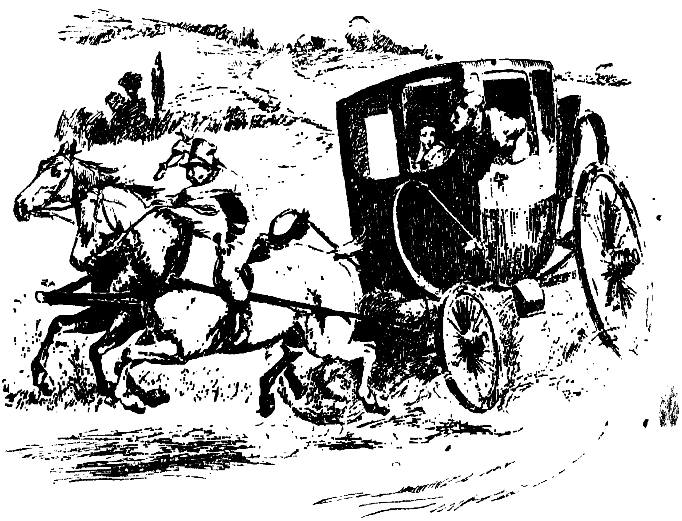
—PROF. RANKINE.

1. Young people who have grown up in the era of railways and of ocean-going steamships hardly realise the vast change which older people have seen, or how great and far-reaching that change is.

2. Even in my own boyhood the waggon for the poor, the stage-coach for the middle class, and the post-chaise for the wealthy, were the universal means of travelling for long distances, there being only two

short railways then in existence—the Stockton and Darlington, opened in 1825, and the Liverpool and Manchester line, opened in 1830.

3. The yellow post-chaise, without any driving seat, but with a postilion dressed like a modern jockey and riding one of the pair of horses, was among the commonest sights on our main roads; and, together with



5. TO GRETNA GREEN IN A POST-CHAISE

the hundreds of four-horse mail and stage coaches, the guards carrying horns or bugles which were played while passing through every town or village, gave a stir and liveliness and picturesqueness to rural life which is now almost forgotten.

4. When I first went to London (I think about 1835) there was still not a mile of railroad in England

except the two above-named, and none between London and any of our great northern or western cities were even seriously thought of. The sites of most of our great London railway termini were then on the very outskirts of the suburbs; Chalk Farm was a genuine farmhouse, and Primrose Hill was surrounded by open fields.

5. A few years later—in 1837–8—I was living near Leighton-Buzzard while the London and Birmingham Railway, the precursor of the present London and North-Western system, was in process of con-

6. THIRD-CLASS TO THE DERBY IN 1845

struction; and when the first section was opened to Watford, I travelled by it to London third-class, in what is now an ordinary goods truck, with neither roof nor seats, nor any other accommodation than is now given to coal, iron, and miscellaneous goods. If it rained or the wind was cold, the passengers sat on the floor and protected themselves as they could.

6. Second-class carriages were then what the very worst of the third-class are, or were a few years ago—closed in, but low and nearly dark, with plain wooden

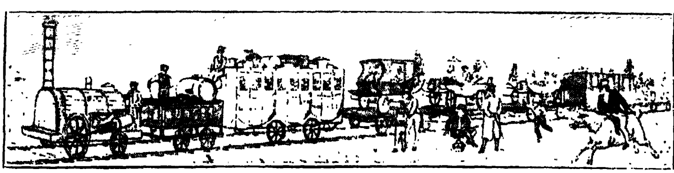
seats—while the first-class were exactly like the bodies of three stage-coaches joined together.

7. The open passenger trucks were the cause of much misery, and some deaths from exposure led to their being somewhat improved; but even then there was evidently a dread of making them too comfortable, so a roof was put to them, also seats, and the sides were a little raised, but left open at the top, the result being a carriage about equal in comfort to our present cattle trucks.

8. At last, after a good many years, the despised third-class passengers were actually provided with carriages of the early second-class type; and it is

7. A SECOND-CLASS TRAIN—LIVERPOOL AND MANCHESTER RAILWAY, 1833

only in comparatively recent times that the greater railway companies began to realise the fact that third-class passengers were so numerous as to be more profitable than the other two combined, and that it

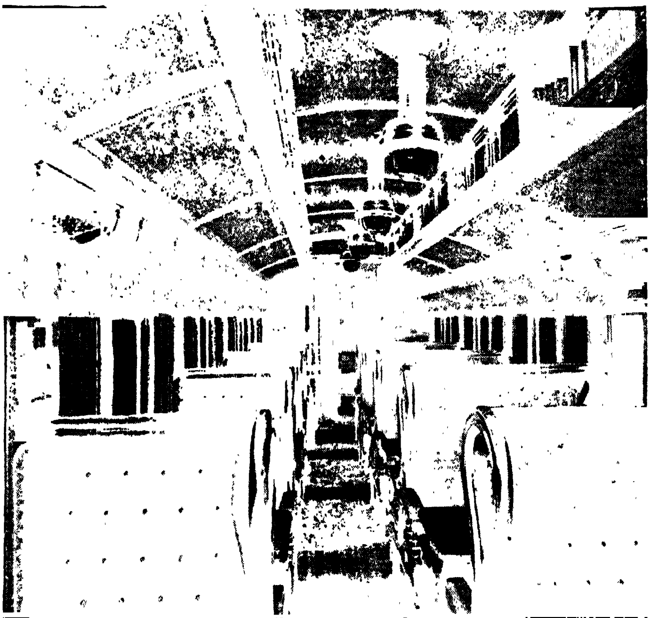


8. A FIRST-CLASS TRAIN—LIVERPOOL AND MANCHESTER RAILWAY, 1833

was worth while to give them the same comfort, if not

the same luxury, as those who could afford to travel more expensively.

9. The continuous progress in speed and comfort is matter of common knowledge, and nothing more need be said of it here. The essential point for our con-



9. THIRD-CLASS DINING-CAR—MIDLAND RAILWAY—1900

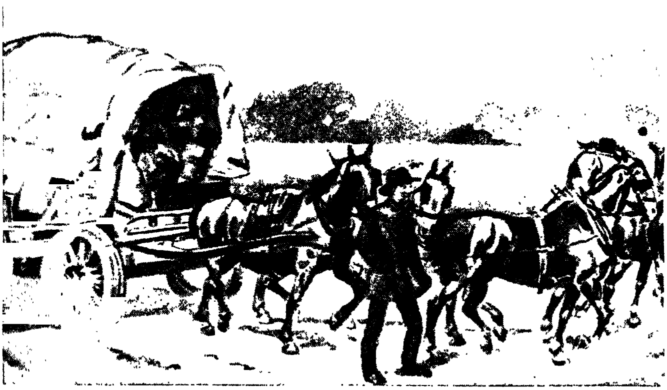
sideration is the radical nature of the change that has been effected wholly within the past century. In order to illustrate this, our next lesson will be devoted to a short account of the modes of travelling in early ages and in various parts of the world.

LESSON 3

ANCIENT MODES OF TRAVELLING

"A Stage Coach will set out for Dover every Wednesday and Friday from Christopher Shaw's, the Golden Cross, at four in the morning, to go over Westminster Bridge to Rochester to dinner, to Canterbury at night, and to Dover the next morning early." —*London Evening Post, 28th March* 1751.

1. In all previous ages, the only modes of travelling or of conveying goods for long distances were by employing either men or animals as the carriers. Wherever the latter were not used, all loads had to be carried by men, as is still the case over a large part of Africa, and as was the case over almost the whole of Tropical America before its conquest by the Spaniards.



10. AN ENGLISH STAGE WAGGON USED DOWN TO 1840 FOR CARRYING GOODS

2. But throughout Europe and Asia, the horse was domesticated in very early times, and was used for riding and for drawing war-chariots; and, throughout

the Middle Ages, pack-horses were in universal use for carrying various kinds of goods and produce, and saddle-horses for riding.

3. All journeys were then made on horseback, and it was in comparatively recent times that wheeled vehicles came into general use in England for travelling in. One of the first English carriages was made for Queen Elizabeth in 1568; the first that plied for hire in London were in 1625, and the first stage-coaches in 1659.

4. But chariots drawn by horses were used, both in war and peace, by all the early civilised peoples. Pharaoh made Joseph ride in a chariot, and he sent waggons to bring Jacob, with his children and household goods, to Egypt. A little later, chariots were sent by the Syrians as tribute to Pharaoh. Homer describes Telemachus as travelling from Pylos to Sparta in a chariot provided for him by Nestor, as shown by the following lines from Pope's translation of the "Odyssey," and chariot-races were held in high esteem by the Greeks and Romans:—

> "The rage of thirst and hunger now suppress'd,
> The monarch turns him to his royal guest;
> And for the promis'd journey bids prepare
> The smooth-haired horses and the rapid car."

5. It is clear, therefore, that in the earliest historic times all the various types of wheeled vehicles were used—for war, for racing, for travelling, and for the conveyance of merchandise. They must also have been used throughout a large part of Europe, since Cæsar found our British ancestors possessed of war-chariots, which they managed with great skill, implying a long previous acquaintance with the domesticated horse and its use in humbler wheeled vehicles.

6. Thus, throughout all past history the modes of travelling were essentially the same, and an ancient Greek or Roman, Egyptian or Assyrian, could travel as quickly and as conveniently as could Englishmen down to the latter part of the eighteenth century.

1. ANCIENT WAR CHARIOT

7. It was mainly a question of roads, and till the beginning of the nineteenth century our roads were for the most part far inferior to those of the Romans. It

is, therefore, not improbable that during the Roman occupation of Britain the journey from London to York or to Bath could have been made actually quicker than a hundred and fifty years ago.

8. We see, then, that from the earliest historic, and even in prehistoric times, till the construction of our great railways in the second quarter of the present century, there had been absolutely no change in the methods of human locomotion; and the speed for long distances must have been limited to ten or twelve miles an hour, even under the most favourable conditions, while generally it must have been very much less.

9. But the railroad and steam-locomotive, in less than fifty years, not only raised the speed to fifty or sixty miles an hour, but rendered it possible to carry many hundreds of passengers at once with punctuality and safety for enormous distances, and with hardly any exposure or fatigue. For the civilised world, travelling and the conveyance of goods have been revolutionised, and by means which were probably neither anticipated nor even imagined fifty years before.

10. Dr. Erasmus Darwin, the grandfather of Charles Darwin, predicted steam-carriages in these lines :—

> "Soon shall thy arm, unconquer'd steam! afar
> Drag the slow barge, or drive the rapid car;
> Or on wide-waving wings expanded bear
> The flying chariot through the field of air."

But he did not foresee our railroads, the enormous cost of which would have seemed to be prohibitory. And we have by no means yet fully developed their possibilities, since even now a railroad could be made on which we might safely travel more than a hundred miles an hour, it being merely a question of expense.

LESSON 4

TRAVEL BY SEA

"How gloriously her gallant course she goes!
Her white wings flying—never from her foes—
She walks the waters like a thing of life,
And seems to dare the elements to strife."

BYRON.

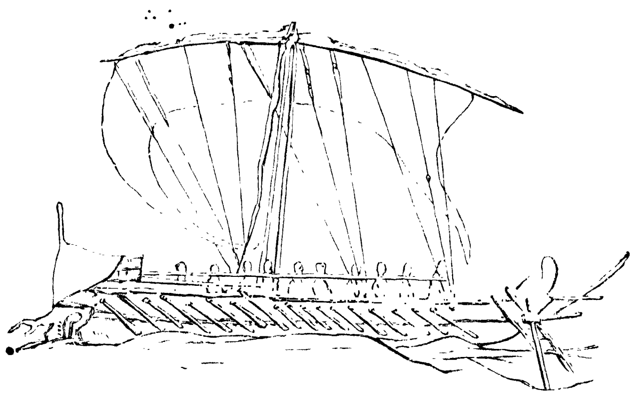
12. ANCIENT GALLEY

1. In sea and ocean travel there has been a very similar course of events, with the same characteristic of a completely new departure, leading to remarkable developments and great possibilities of still greater results in the future.

2. From the earliest dawn of history, we find that men used boats of various forms and sizes, and propelled them either by oars or by the use of sails to catch the wind, in exactly the same manner as we do to-day. And even in prehistoric times they did the same; for canoes have been found among the relics of the lake-dwellers of Switzerland, who lived in what is termed the Bronze Age—that is, before iron came into use. In the alluvial deposits of the Clyde, also, large numbers of canoes have been found, some more than twenty feet above the sea-level, and apparently belonging to the still earlier Stone Age.

3. All the great nations of antiquity—Phœnicians, Carthaginians, Persians, and Greeks—had fleets of war-vessels, and great naval battles were as common then

as now. Similar fleets certainly existed more than a thousand years before Christ, since they were common in the time of Homer; and such inventions are of very slow growth. The largest of these ships were propelled by hundreds of slaves, using enormous oars, often in three or four rows one above another; and these galleys, as they were called, could move against wind and tide almost as well as our older steam-ships. When the wind was favourable, sails were used, very much as we use them now. The rowers of the galleys



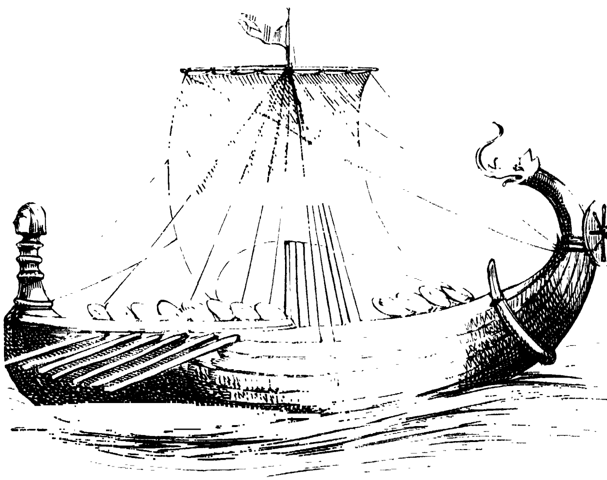
13. SMALL ROMAN GALLEY (FROM TRAJAN'S COLUMN)

were chained to their seats, and overseers with whips made them pull with all their strength, whenever great speed was necessary.

4. About 500 years B.C., a Carthaginian, named Hanno, sailed with a fleet of ships out of the Mediterranean Sea, and along the coast of Africa to near the equator. This was the first voyage of discovery of which we have any record, and its commander described some "hairy people" he met with under the name of "Gorilla," and this word has, therefore, been

applied to distinguish the great ape of Tropical Africa. As there are no hairy people in Africa, it is not improbable that Hanno really saw either gorillas or chimpanzees, and mistook them for hairy men.

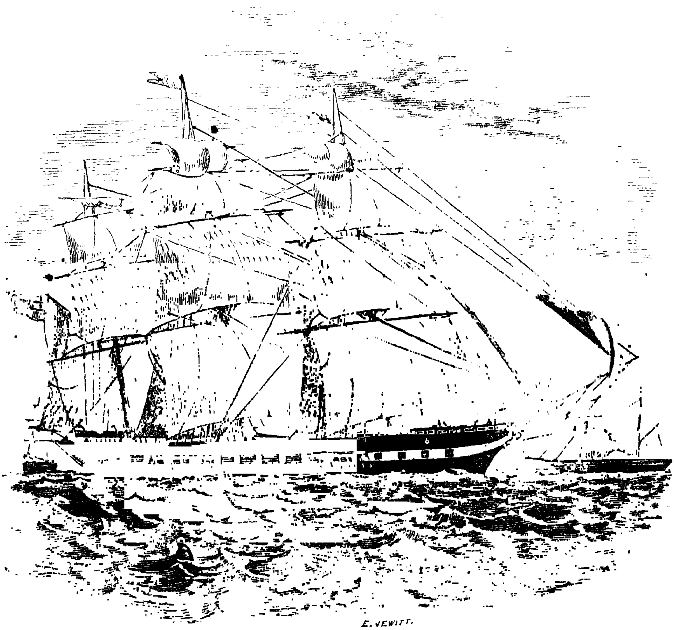
5. The next great feat of navigation was the discovery of the northern coasts of America, as far south as New England, by the Northmen about nine hundred years ago; so that the first discovery of America was



14. NORMAN SHIP (FROM BAYEUX TAPESTRY)

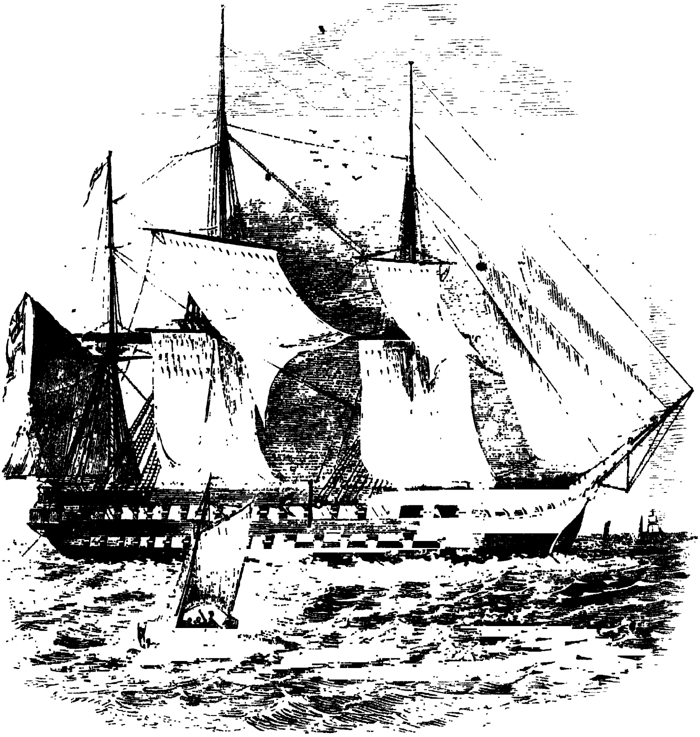
made nearly five hundred years before the time of Columbus, who crossed the Atlantic Ocean at its widest part, from Spain to the West Indies, in 1492, certainly the boldest feat in navigation that has ever been performed. In 1497, the Portuguese captain, Vasco da Gama, sailed round the Cape of Good Hope to Calcutta; and thus discovered the ocean route to India.

6. From that time sailing ships were gradually improved, till they culminated in our magnificent frigates for war purposes and the clipper ships in the China and Australian trade, which were in use up to the



15. IRON CLIPPER SHIP "TAYLEUR," 1853

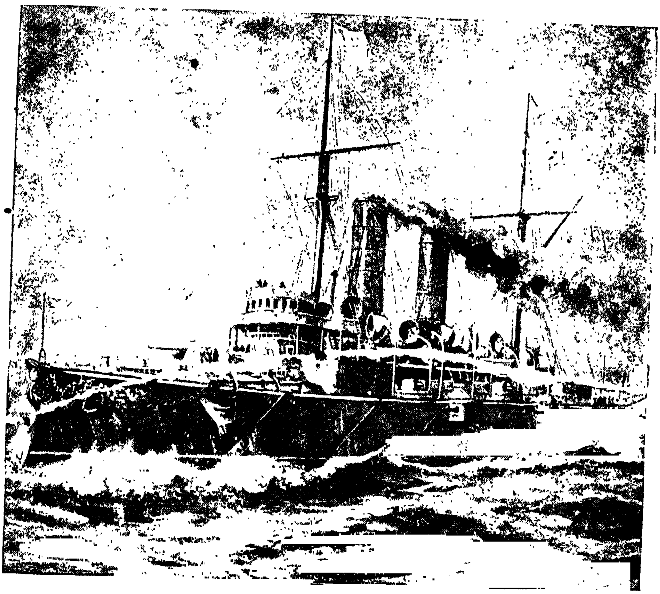
middle of the past century. But, during all this long course of development, there was no change whatever in principle, and the grandest three-decker or full-rigged clipper ship was but a direct growth, by means of an infinity of small modifications and improvements, from the rudest sailing boat of the primeval savage.



16. THE COLLINGWOOD, TWO-DECKER, MIDDLE OF NINETEENTH CENTURY

7. Then, at the very commencement of the last century, the totally new principle of propulsion by means of paddle-wheels driven by steam-engines began to be used, at first experimentally and with many failures, on rivers, canals, and lakes, till about the year 1815 coasting steamships of small size became rather common.

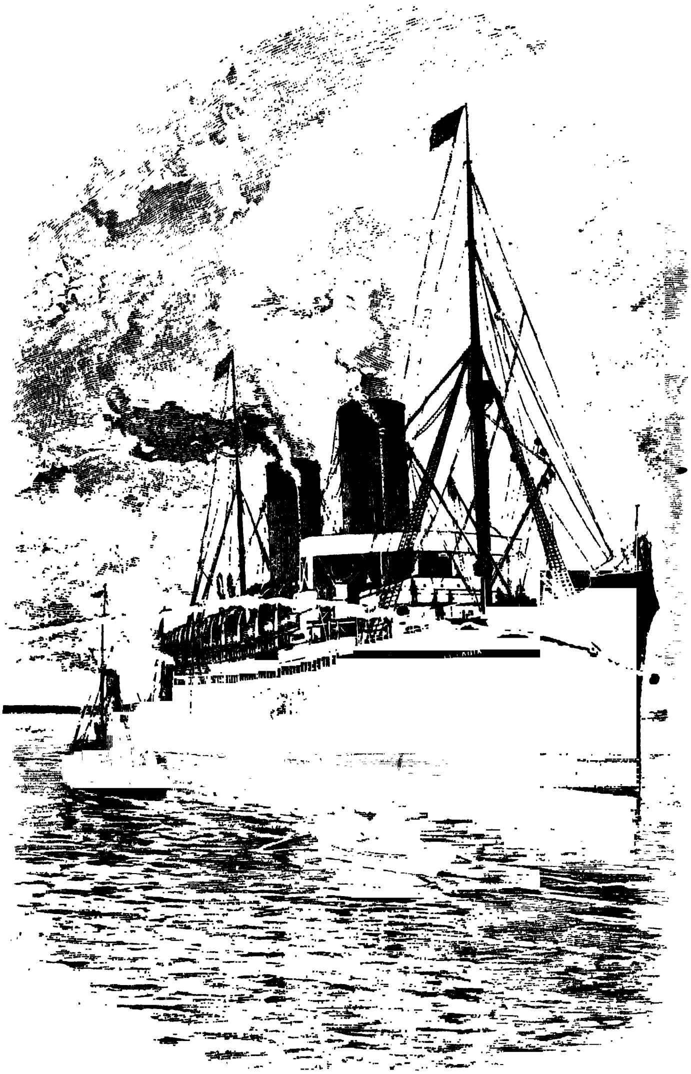
8. These were rapidly improved; but it was not till the year 1838 that the *Great Western*, of 1340 tons and 400 horse-power, made the passage from Bristol to New York in fourteen days, and thus began that system of ocean steam-navigation which has since developed to such an enormous extent. The average speed then attained was about ten miles an hour, but



17. A WARSHIP (H.M.S. BLENHEIM) 1900

this has now been more than doubled, and is still increasing.

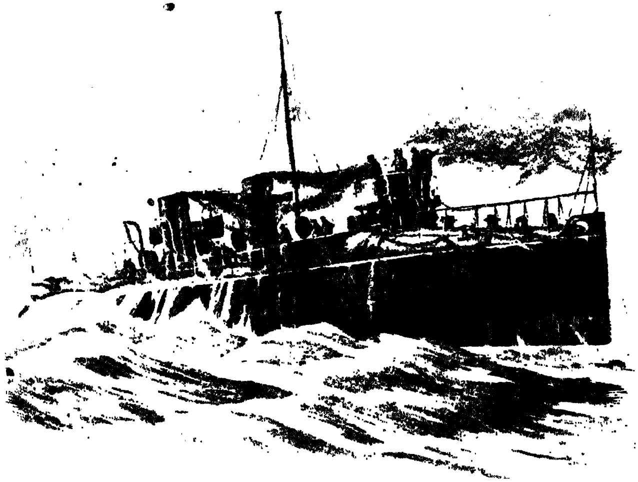
9. This is partly due to the use of the screw instead of the paddle-wheel, partly to a great improvement in the construction of steam-engines, but perhaps mainly to the enormous increase in the size of the



18. AN ATLANTIC LINER IN 1900

ships used. But the horse-power needed to attain this high speed has increased in a far higher proportion; and it is only the much greater size and capacity for carrying enormous quantities both of passengers and goods that render such high speeds and enormous consumption of coal profitable.

10. The latest great advance in steam-navigation is the invention of the steam-turbine, a very simple and economical form of engine, and the use of a number of screws revolving at high velocities. Some of the small



19. A TORPEDO-BOAT, 1900

torpedo-boats and torpedo-destroyers built in this way have attained a speed of from thirty to forty miles an hour, and it is possible that even higher velocities may be reached. Many new forms of vessel, such as the cigar-shaped and the roller-boats, have not been adequately tried; and there are other suggested forms by means of which greater steadiness and speed may yet be obtained.

LESSON 5

THE CYCLE AND MOTOR CAR

"The spirit of the time shall teach me speed."
—SHAKESPEARE.

1. Almost as remarkable as our railroads and steamships is the new method of locomotion by means of the bicycle and tricycle.

2. The idea of a carriage propelled by the driver was carried out, in 1766, in France, by a movement—something like a treadmill—turning the hind-wheels of a light carriage; but the forerunner of the modern bicycle was the hobby-horse or dandy-horse of the eighteenth century, in which the rider pushed himself along with his feet on the ground.

3. The first true bicycle, however, was made in 1836, by a Scotchman named Dalzell. It was made of wood and iron, and was very like one of the modern low safety bicycles in general form, though exceedingly clumsy. Yet the inventor beat the mail-coach in an hour's race, so that he must have travelled at least twelve miles an hour.

4. Since that date, the whole of the advance has consisted in various modifications of the method of applying the leg-power to the driving wheels, in increased lightness combined with strength, in perfection of mechanical construction, and in various methods of diminishing friction and jolting over rough roads. This has been effected by innumerable trials of almost every conceivable mode of construction, and the gradual adoption of those which led to the best results.

5. The first great improvement was in using india-rubber tyres. These were at first (1868) mere bands, which were afterwards made even two inches thick;

while the modern inflated or pneumatic tyres were only invented in 1888. The wire tension spokes, in place of the thick spokes of ordinary wheels and of the early bicycles, were introduced about 1870; while ball-bearings to diminish friction were adopted in 1877. The various modes of gearing by which

20. A LADY CYCLIST, 1900

smaller wheels may be made to revolve at a greater speed came into use soon afterwards, and these rendered it possible to construct a safety bicycle so as to be used by women as well as by men. It is to the four improvements just described that modern bicycles and tricycles owe their great speed combined with comfort to the rider. The number of trials and failures required

to attain this result may be estimated by the fact that, in the year 1884, no less than 220 distinct kinds of tricycles were on sale, so that the number of different constructions of bicycles and tricycles have probably been over a thousand, and no doubt many more will be made.

21. A CYCLE RACE, 1900

6. It is a very interesting fact that three out of the four methods of rapid locomotion we now possess should have attained about the same maximum speed. The racehorse, the steamship, and the bicycle have each of them reached thirty miles an hour. The

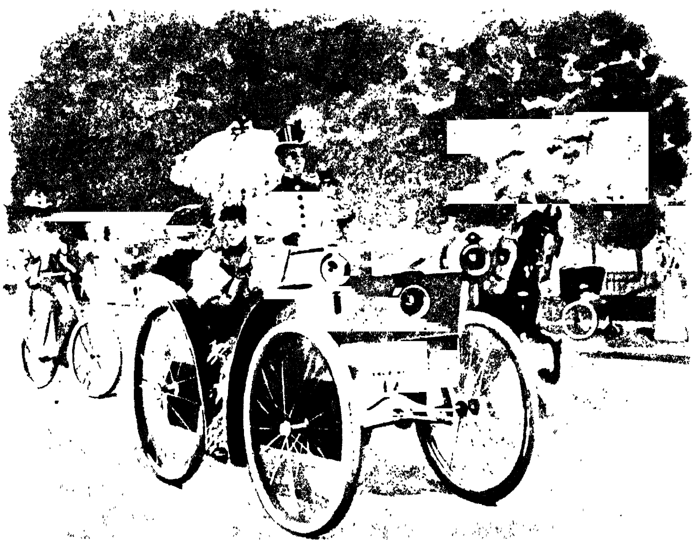
horse is, however, close upon, if it has not actually attained, its utmost limits; the bicycle can already beat the horse for long distances, and will certainly go at higher speeds for short ones; while the steamship will also go much quicker, though how much no one can yet say.

7. It is certainly a most wonderful and unexpected fact, that while the fastest athletes have not been able to run twelve miles in an hour, a mode of progression should have now been perfected by means of which any fairly strong and healthy person can exceed that speed for several successive hours. With comparatively little fatigue, most good cyclists can travel, over fairly good roads, about a hundred miles in a day, while only a few could walk even fifty miles without very much greater labour. The cycle is thus shown to be a new departure, unlike anything that has gone before it.

8. More recently, cycles and various forms of carriages have been made which are propelled by either steam, gas, petroleum, or electricity; but as these are, in principle, identical with the steam-locomotive, they need not be further discussed here. They have, however, a very important bearing on the health and pleasure of those who live in towns, because, as soon as they are sufficiently improved to supersede horse-power, all streets and roads within town limits can be asphalted; and, with the universal use of rubber-tyres, they will be both noiseless and almost indestructible, while, by a daily sluicing, they may be kept as clean and wholesome as a well-kept dwelling-house. This is one of the great improvements that the twentieth century will probably carry out, and which some who read these lines will probably live to enjoy.

9. We see, then, that during the nineteenth century

three distinct modes of locomotion have been originated and brought to a high degree of perfection. They are altogether different in principle from anything which had gone before. Up to the very times of men now living, all our locomotion was on the same old lines which had been used for thousands of years.



22. A MOTOR CARRIAGE, 1900

It had been improved in details, but without any alteration of method and without any very great increase of efficiency. The principles on which our present methods rest are new; they already far surpass anything that could be effected by the older methods, with wonderful rapidity they have spread over the whole world, and they have in many ways modified the habits, and even the modes of speech, of all civilised peoples.

10. This vast change in the methods of human locomotion, already so ubiquitous that, to the younger generation, their absence rather than their presence would be considered remarkable, has been almost wholly effected within the writer's memory, and is of itself sufficiently striking and important to justify the appellation of "The Wonderful Century" to that period which has witnessed its rise, its progress, and the maturity of its development.

LESSON 6

LABOUR-SAVING DEVICES (1)

"Work—work—work
 Till the brain begins to swim;
Work—work—work
 Till the eyes are heavy and dim!
Seam and gusset and band,
 Band and gusset and seam,
Till over the buttons I fall asleep,
 And sew them on in a dream."

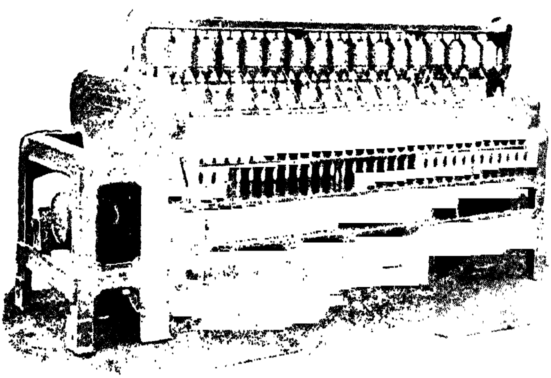
—HOOD.

1. The invention and partial development of much of our modern machinery dates from the last century, and our most advanced appliances for the manufacture of the various textile fabrics and hardware are mostly improvements of, or developments from, the older machines. Thus the old spinning-wheel, which during the greater part of the last century was used in farm-houses and cottages all over the country, is now replaced by the large spinning mules, first invented by Hargreaves in 1764, and by Arkwright a little later, and greatly improved by Crompton and others, till we now have machines that will produce hundreds of threads far more rapidly than the old hand-wheel could produce one. These, taken in connection with the

great improvements in steam-engines, have multiplied many times over the efficiency of human labour, but do not otherwise specially interest us here.

23. THE OLD SPINNING-WHEEL

2. There are, however, a few inventions which have the character of quite new departures, since not only do they greatly diminish labour, but they perform by mechanical contrivances operations which had been supposed to be beyond the power of machinery to execute. The more prominent of these are the sewing-machine, the type-writer, and the combined reaping, thrashing, and winnowing machine, of which a brief account will be given.



24. THE SPINNING FRAME
(By permission of the Makers, Messrs. Brooks & Doxey, Manchester)

3. The sewing-machine, now so common, exercised the ingenuity of mechanicians for a long period before it arrived at sufficient perfection to be suitable for general use.

25. THE HAND-SEWING OF 1800 HAS BEEN LARGELY SUPERSEDED

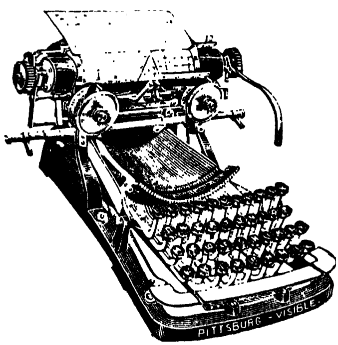
4. The earlier machines were for embroidering only; then, about 1790, one was made for stitching shoes and other leather work, but it does not seem to have come into general use. A crocheting-machine was patented in 1834; somewhat later, one for rough basting; but it was not till 1846, that the first effective lock-stitch sewing-machine was made by Elias Howe, of Cambridge, Massachusetts.

5. Henceforth sewing-machines were rapidly improved and adapted to every variety of work; but the difficulty of the problem to be solved is shown by the unusually long process of gradual development, much of the mechanical talent of both hemispheres being occupied for nearly a

26. IN 1900 BY THE USEFUL SEWING-MACHINE

century before the various machines so familiar to-day were perfected. There are now special machines for making button-holes and for sewing on buttons, for carpet-sewing, for pattern-sewing, for leather work, and for the special operations required in the making and repairing of shoes.

6. Boot and shoe making by machinery in large factories has entirely grown up since the sewing-machine was proved to be adapted for almost every kind of sewing-work. As a result, machine-made boots and shoes are very cheap, but they are usually of inferior quality to the old hand-made articles; and first-class work is quite as dear as it was fifty or sixty years ago, or even dearer.



27. TYPEWRITER

7. The typewriter is a still later invention, and though perhaps less difficult than the sewing-machine, yet it involves more complex motions and adjustments, so that the perfection it has so quickly attained is very remarkable.

8. If we consider that about sixty separate types, including small letters, capitals, spaces, stops, &c., have to be so arranged and so connected as to be brought in any order whatever to a definite position, so as to form the successive letters and spaces in lines of printed characters, and then, being properly inked, must be brought into contact with the paper so as to produce a clear impression, and that all the motions of the machinery required must be the result of a single

pressure on a key for each letter, following one another as rapidly as possible, we shall have some idea of the difficulties which have had to be overcome.

9. Yet, so great are the resources of modern mechanism, and the ingenuity of our mechanists, that the required result has been attained in many different ways, so that we may now choose between half-a-dozen forms of typewriters, no one of which seems to be very markedly superior to the rest. The above illustration shows the latest and simplest form of writing-machine, in which the mechanism is so arranged that the writing is always visible.

LESSON 7

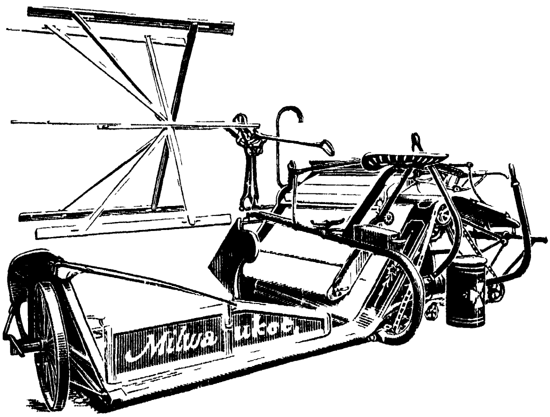
LABOUR-SAVING DEVICES (2)

> "Wonderful chair! Wonderful houses! Wonderful people!
> Whirr! whirr! all by wheels! Whizz! whizz! all by steam"
> —*Eothen.*

1. More important, perhaps, to mankind generally are the harvesting-machines, which render it possible to utilise one or two fine days to secure a harvest.

2. Reaping-machines have long been used in this country, and are even mentioned by Pliny as being used in his day in Gaul. The first, however, to come into general use in this country was that made by Mr. Bell in 1826; and from that time successive improvements were made in England, Australia, and America. These were followed by combined reapers and binders, which left the crop ready for carting to the barn. But this, when the distance was great, did not save the grain from injury by wet, besides requiring much labour and a careful process of stacking to preserve it.

3. In America, a harvesting-machine has been at length brought to perfection, which not only reaps the grain, but thrashes it, winnows it, and delivers it into sacks ready for the granary or the market at one operation. This machine, with two men, will, in one fine day, secure the crop from ten or fifteen acres, with a minimum of labour.



28. A TYPICAL AMERICAN HARVESTING MACHINE, EMBODYING THE LATEST IMPROVEMENTS

4. In the great wheat-fields of California and Australia, with an almost uniformly dry climate at harvest-time, it is this saving of labour which is the chief consideration; but in our treacherous climate, where a few days' delay may mean the partial or complete ruin of the crop, such machines will be doubly valuable by enabling farmers to utilise to the utmost every fine day after the grain is ripe.

5. I had the pleasure of seeing this wonderful machine at work in California in 1887. It was then

propelled by sixteen small mules harnessed behind, so as not to be in the way; but steam power is now used. Considering what it effected, it was wonderfully light, compact, and simple; and when agriculture is treated as a work of national importance, such machines will render us, to a considerable extent, independent of the weather, and will therefore become a necessity.

6. The three mechanical inventions here briefly described were conceived in the first half, and brought to perfection in the second half of the century.

7. They each mark a new departure in human industry, inasmuch as they effect, by means of machinery and at one operation, what had previously been performed by human labour directed by a hand or arm rendered skilful by long practice, and sometimes requiring several distinct operations. They had been thus performed during the whole preceding period of human history, or so long as the particular kind of work had been done; so that though of less general use and of less importance, they have the same distinguishing features which we have found to characterise our new methods of locomotion.

8. There are, of course, innumerable other remarkable mechanical inventions of the century in almost every department of industry—such as the Jacquard loom for pattern-weaving, invented by a weaver of Lyons in the early years of the century, who also made the first machine for making nets; revolvers and machine-guns, iron ships, screw-propellers, &c.; while machinery has been extensively applied to watch-making, screw-cutting, nail-making, printing, and a hundred other purposes.

9. But none of these inventions, though often highly ingenious, are of very high importance in them-

selves, or possess the special characteristics of being new and quite distinct departures from what has been done before, and they cannot therefore rank individually among those greater discoveries which pre-eminently distinguish the Nineteenth Century.

LESSON 8

29. A MAIL TRAIN, 1900

THE CONVEYANCE OF THOUGHT

"As thick as hail
Came post with post; and every one did bear
Thy praises in his kingdom's great defence
And poured them down before him."
--*Macbeth.*

1. The history of the progress of communication between persons at a distance from each other has gone through three stages which are radically distinct.

2. At first it was dependent on the voice or on gestures, and a message to a friend (or enemy) at a distance could only be sent through a messenger, and was liable to distortion through failure of memory.

3. The heralds and ambassadors of early times thus

communicated orders from kings to their subjects, or conveyed messages from one king to another.

4. Another mode of communication in use from very early times was by signals, visible at a great distance and having some definite meaning. Such were the beacon-fires which were lighted on all our highest hills and mountains to indicate the presence of an invader; and it was by this means that the appearance of the Spanish Armada in the English Channel was spread in a few hours over the whole of England, as finely described in Macaulay's well-known poem.

5. In order to convey more detailed information, the semaphore was used by many European Governments towards the end of the eighteenth century. In England, lines of semaphore signals were established between Deal, Portsmouth, and Plymouth, and the Admiralty in London. They consisted of towers on elevated points from five to ten miles apart, on the top of which six shutters were so arranged that by opening or closing them in various combinations, messages could be accurately spelt out. A man stationed at each tower with a telescope repeated exactly the motions of the shutters, and so rapidly was this done that a single combination could be conveyed from London to Portsmouth, or the reverse, in about a minute.

6. A modification of this method is still used in railway signalling, and more elaborately by means of signal-flags at sea. By means of signal-books containing almost every sentence that can be wanted, conversation between different ships at some miles' distance can be carried on with speed and accuracy.

7. But when the art of writing became general, a new era of communication began. Letters were

capable of conveying secret information and copious details, which could not be safely entrusted to the uncertain memory of an intermediary; and a single messenger could convey a large number of letters to various persons on the way to his ultimate destination.

8. Henceforth the progress of communications was

30. AN ENGLISH MAIL-COACH IN 1800

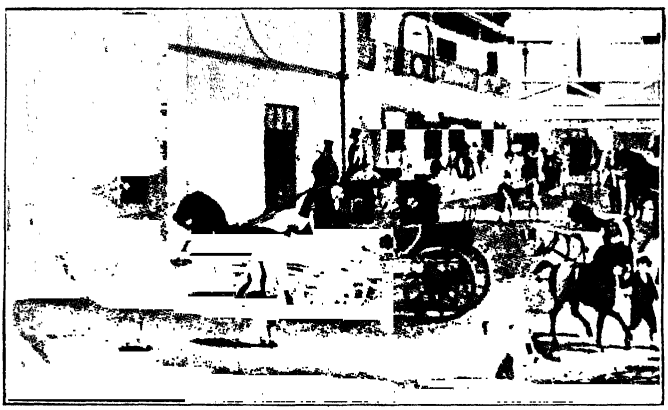
bound up with that of locomotion, and, as civilisation advanced, arrangements were made for the conveyance of letters at a comparatively small cost.

9. A post-office for the public service was first established by some Continental merchants in the fourteenth century; but it was not till the time of Charles I., that anything of the kind was to be found

in England, and then it was mainly for the purpose of keeping up a communication between London and Edinburgh, and the intervening large towns, for Government purposes.

10. It was, however, the starting-point of our existing postal system, which has been gradually extended under the direction of the Postmaster-General, and has continued to be a Government monopoly to our day. The letters were carried on horseback till 1783, when mail-coaches were first introduced; and these led to a great improvement in our main roads, and the extension of the postal service to every town and village in the kingdom.

LESSON 9



31. MAIL-COACH STARTING FROM THE SWAN WITH TWO NECKS, LUD LANE, 1800

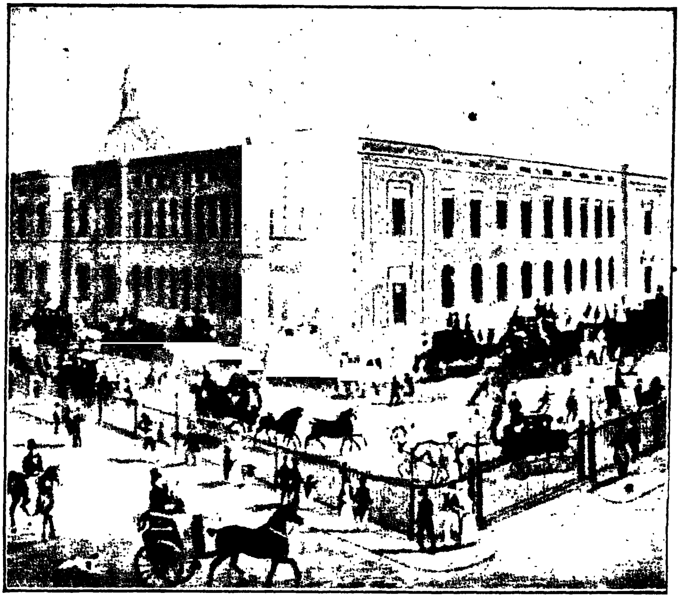
THE POST-OFFICE

"Every morning as sure as the clock,
Somebody hears the postman's knock."

1. But even with good roads and mail-coaches, the actual time taken in the despatch of a letter to a

distant place, was little, if any, shorter than had been possible from the earliest times by means of relays of runners on foot, or by swift horsemen.

2. The great improvement has consisted in the regularity and economy of the postal service. The introduction of railways and steamships enabled much



32. VIEW OF THE GENERAL POST-OFFICE, ST. MARTIN'S-LE-GRAND, IN 1832, WITH THE ROYAL MAILS PREPARING TO START

greater speed to be secured; but the greatest and most beneficial improvement in the administration of the Post-Office was that inaugurated by Rowland Hill in 1840.

3. The rule, then first introduced, of an uniform charge irrespective of distance, is one of those entirely new departures so many of which characterise the past

century, and which not only produce immediate beneficial effects, but are the starting-points of various unforeseen developments.

4. It was founded in this case on a careful estimate of the various items, which make up the cost of the carriage and delivery of each letter; and it was shown that the actual conveyance, even for the greatest distances, was the smallest part of the cost when the number of letters is large, the chief items of expense being the office work—the sorting, stamping, packing, &c.—and the final delivery to the receiver's house, all of which are quite independent of the distance the letter is carried.

5. The old system, therefore, of increasing the charge for postage in proportion to distance was altogether unreasonable, because the cost of conveyance was hardly perceptibly increased; and if the Post-Office was considered to be a public service for the public benefit only, the people had a right to demand that they should pay only in proportion to the cost.

6. Yet this simple principle was not at first, and is not even now, fully carried out. For thirty years, from 1840 to 1871, the postage was increased equally with each successive increment of weight, the half-ounce letter being a penny, while one of two ounces was fourpence.

7. But as the chief items of expense—the office work and delivery—were the same, or nearly the same, in both cases, the double or quadruple charge was entirely opposed to the principle on which the uniform rate was originally founded. Accordingly, in 1871, when an ounce letter was first carried for a penny, the charge for two ounces was fixed at three-halfpence, while a four-ounce letter was taken for twopence.

8. This acknowledged and common-sense principle,

upon which our whole system of cheap postage is founded, has not yet been applied to the charges of the Postal Union. For a foreign letter which is a

33. NEWSPAPER SORTING-ROOM, G.P.O., LONDON

fraction over the half-ounce is charged fivepence, or double, and one over an ounce and a half tenpence, or four times that of the half-ounce letter, although

an extra halfpenny would probably cover the extra cost of the service in both cases.

9. Since 1899, the weight of the inland letter has been increased to four ounces for a penny, each additional two ounces being charged a halfpenny, making the charge the same as in book postage. About the same time, a number of British Colonies agreed to a reduced letter postage of one penny per half-ounce.

10. The same inability of the official mind to carry out an admitted principle is seen also in the case of Postal Orders.

11. The cost to the Post-Office of receiving and paying money is exactly the same whether the amount is eighteen-pence or fifteen shillings, and there is neither justice nor common-sense in charging three times as much in the latter case. There is no risk, because the money is paid in advance; and as the amounts taken in and paid out for Postal Orders are sure to be approximately equal, it is difficult to see what justification there is for making any difference in charge.

12. The same objection applies to Money Orders; and as there is doubtless a certain percentage of both which, from various causes, are never presented for payment, the profit to the Post-Office must be greater in case of the higher amounts, which is another reason why these should not be exceptionally taxed.

13. When the railways are taken over by the State, to be worked for the good of the community only, this principle will admit of great extension, each increment of distance being charged at a lower rate, just as is each increment of weight in our inland letters. But it will then be still more economical to do away with tickets and ticket-clerks and booking-offices altogether, and allow everybody to travel free. When this is the

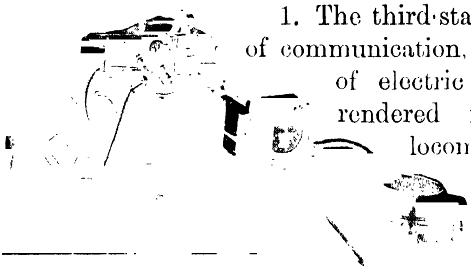
case there may not be very much more travelling than now, but everybody will receive an equal benefit from a service which will be paid for by themselves.

LESSON 10

THE TELEGRAPH AND THE TELEPHONE

"The electric chain, whose mystic girth,
Makes distance but a span;
And science covering all the earth
With benefits for man."

—CHARLES MACKAY.



34. TELEGRAPH INSTRUMENT

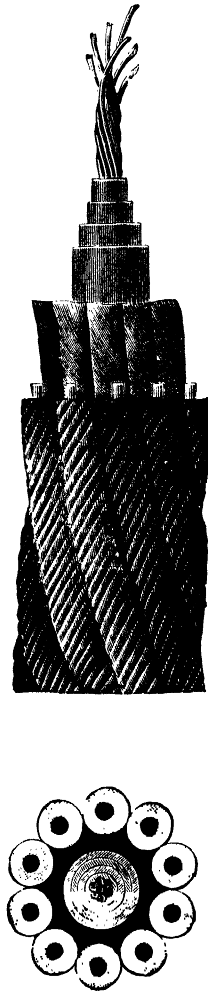
1. The third stage in the means of communication, when by means of electric signals it was rendered independent of locomotion, is that which has especially distinguished the past century. The electric telegraph serves us as a new sense, enabling us to communicate with friends at the other side of the globe almost as rapidly and as easily as if they were in different parts of the same town. The means of communication we now use daily would have been wholly inconceivable to our ancestors a hundred years ago.

2. About the middle of the last century, it was perceived by a few students of electricity that it afforded a means of communication at a distance, since an electric shock sent through a wire would cause two pith balls to diverge at the end of the wire. But it was not till the year 1837, that the

efforts of many simultaneous workers overcame the numerous practical difficulties, and the first electric telegraph was established.

3. The principle on which the modern electric telegraph depends was discovered by Oersted of Copenhagen in 1819. If an electric current from a small galvanic battery passes along a wire above an ordinary magnetic needle and parallel to it, the needle suddenly moves to one side or the other according to the direction of the current, and returns to its original position when the current ceases. If the wire is passed several times over and under the needle, forming a coil, the strength and rapidity of the action on the magnet is increased; and thus the signals are rendered more clear and can be more rapidly repeated. It is by various applications of this principle that all electric telegraphs are now worked.

4. The utility of this mode of communication was so great, especially in the working of the railways, then being rapidly extended over the kingdom, that it soon came into general use; but hardly any one at first thought that it would ever be possible to lay wires across the ocean depths to distant con-



35. THE SECOND ATLANTIC CABLE

tinents. Yet, step by step, with wonderful rapidity, even this was accomplished.

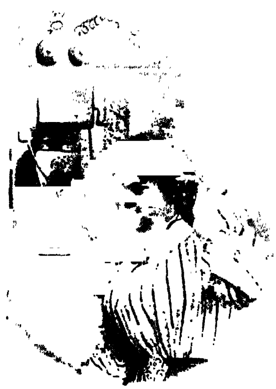
5. The first submarine line was laid from Dover to Calais in 1851; and only five years afterwards, in 1856, a company was formed to lay an electric cable across the Atlantic. The cable, 2500 miles long and weighing a ton per mile, was successfully laid, in 1858, from Ireland to Newfoundland; but owing to the weakness of the electric current, and perhaps to imperfections in the cable, it soon became useless, and had to be abandoned.

6. After eight years more of invention and experiment, another cable was successfully laid in 1866. Its construction is shown by the cuts on the previous page. The central core consists of seven copper wires—the actual conducting cable. This is protected by four sheathings of gutta-percha. Outside this is a strong coating of woven jute, and over this is an external cable formed of ten iron wires, each separately covered with hemp and twisted together. This bears the strain in laying the cable; while the shore ends are still more strongly protected against injury by waves or by rubbing against rocks. There are now no less than fourteen lines across the Atlantic, while all the other oceans have been electrically bridged, so that messages can be sent to almost any part of the globe at a speed which far surpasses the imaginary power of Shakespeare's goblin Puck, who boasted that he could "put a girdle round about the earth in forty minutes."

7. We are now able to receive accounts of great events almost while they are happening on the other side of the globe; and owing to difference of longitude, we sometimes can hear of an event apparently before it has happened. If some great official were to die

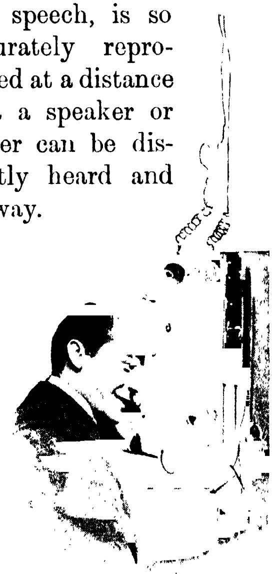
in Calcutta at sunset, we should receive the news soon after noon on the same day.

8. As a result of the numerous experimental researches necessitated for the continuous improvement of the electric telegraph, the telephone was invented, an even more marvellous and unexpected discovery. By its means, the human voice, in all its countless modifications of quality and musical tone, and its most complex modulations during speech, is so accurately reproduced at a distance that a speaker or singer can be distinctly heard and understood hundreds of miles away.



36. BRIGHTON

9. This is not an actual transmission of the air-waves set up by the vocal organs, as in the case of a speaking-tube, but a true reproduction by means of two vibrating discs, the one set in motion by the speaker, while the electric current causes identical vibrations in the similar disc at the end of the line, and these vibrations reproduce the exact tones of the voice so as to be perfectly intelligible.



37. LONDON

10 At first telephones could only be worked suc-

cessfully for short distances, but by continuous improvements the distance has been steadily increased, so that in America there is a telephone line now in operation between New York and Chicago, cities about a thousand miles apart.

11. Those who have read Mr. Bellamy's wonderful story, "Looking Backward," will remember the concerts continuously going on day and night, with telephonic connections to every house, so that any one could listen to the very best obtainable music at will.

12. But few persons are aware that a somewhat similar use of the telephone is actually in operation at Buda-Pesth in the form of a telephonic newspaper.

13. At certain fixed hours throughout the day a good reader is employed to send certain kinds of news—such as politics, war, markets, sports—along the wires which are laid to subscribers' houses and offices, so that each person is able to hear the particular news he desires, without the delay of its being printed and circulated in successive editions of a newspaper. It has now existed several years, and is a complete success.

14. We thus see that during the past century two quite distinct modes of communication with persons at a distance have been discovered and brought into practical use, both of which are perfectly new departures from the methods which, with but slight modifications, had been in use since that early period when picture-writing or hieroglyphics were first invented.

15. In the facilities and possibilities of communication with our fellow-men all over the world, the advance made in the Nineteenth Century is not only immensely greater than that effected during the whole preceding period of human history, but is altogether marvellous in its results. And it is also much greater in amount than the almost simultaneous advance in facilities for locomotion, great as these have been.

LESSON 11

38. SAVAGES OF STONE AGE OBTAINING FIRE

FIRE AND LIGHT

'Put out the light, and then—Put out the light!
If I quench thee, thou flaming minister,
I can again thy former light restore,
Should I repent me:—but once put out thy light,

> Thou cunning'st pattern of excelling nature,
> I know not where is that Promethean heat
> That can thy light relume."—SHAKESPEARE.

1. It seems probable that the discovery of the use of fire, and of some mode of producing it at will, constituted the first important advance of primitive man towards obtaining that command over nature which we term civilisation.

2. How long ago it is since that first step was taken, we have no means of determining. The palæolithic cave-dwellers, who were entirely without metals, yet made use of fire, and no tribes of men have been found who were wholly unacquainted with it.

3. It was probably first utilised in volcanic districts, where sticks may often be ignited by thrusting them into cavities in old lava streams.

4. In other regions, trees are often ignited when struck by lightning; and when this was first observed, the agreeable warmth, the ease with which the fire could be kept up by adding fresh fuel, the cheerful blaze at night, and the pleasant taste imparted to many kinds of food by roasting, would almost certainly lead to its careful preservation and its distribution to other families and tribes.

5. When once used, the inconvenience of losing it would be so great, that any clue to its mode of production would be followed up.

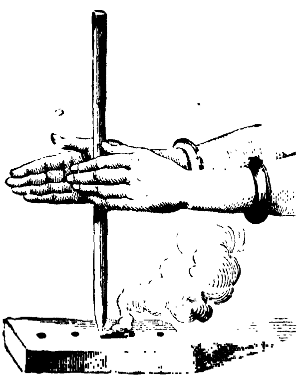
6. It is said that trees are sometimes ignited by the friction of dry branches which happen to touch each other when violently rubbed together during a strong wind.

7. When this was observed for the first time by some thoughtful savage, and he actually found that strong rubbing did make things hot, he would be encouraged to use his utmost efforts to imitate the effect produced by nature.

8. After many unsuccessful trials, he would at length succeed; and the important news would be rapidly communicated to adjacent tribes, and thus spread over a whole continent.

39. MAKING FIRE BY RUBBING WOOD

9. As a matter of fact, this method of producing fire by friction is that most common among savages in all parts of the world; and since it requires only materials that are almost everywhere at hand, it descended even to some civilised peoples. It is, however, a rather troublesome process, requiring a considerable amount of skill and perseverance; hence some of the lowest savages, such as the Tasmanians, are said to have been without the knowledge of it, keeping their fires constantly alight, or, when accidentally extinguished, obtaining it from some adjacent tribe. Perhaps, however, the dampness of their forests rendered it practicable only during very dry seasons.



40. A FIRE-DRILL

10. The methods adopted by savages vary in different countries. One of the commonest is by violently rubbing a piece of very hard pointed wood upon a softer and very dry piece. After a time the wood gets hot, and as the rubbing is

then continued very rapidly, some of the dust is at length ignited, and by careful blowing and the addition of very fine dry shavings a flame is produced. This method I have myself seen used by the natives of the Amazon Valley; but very few Europeans can succeed in performing it.

11. A more common and somewhat easier method is that which Mr. Tylor calls the fire-drill. This is a hard pointed piece of wood pressed upon a flat piece of softer wood and made to revolve rapidly by being rubbed between the palms of the hands. This is used in the East from India to Australia. An improvement on this is used by the Esquimaux, and also in North America and in India. This is by having the string of a small bow twisted once round the stick, by which a very rapid motion can be given to it which soon produces a flame, as shown in the illustration.

LESSON 12

FIRE-GETTING

"The fire i' the flint
Shows not till it be struck.
Those that with haste will make a mighty fire
Begin it with weak straws."—SHAKESPEARE.

1. The method of fire-getting by striking out sparks from iron or steel by a piece of flint, was also used by some savages, though, owing to the difficulty of getting suitable materials, it only became general after the discovery of how to produce iron from the ore. But the Fuegians, always considered to be a very low race of savages, were found by the earliest voyagers to produce fire by striking sparks from iron pyrites with a piece of flint; and the same method was used by some of the tribes of North American Indians.

2. The convenience and rapidity of this method led to its almost universal use as soon as iron became common, since various other stones besides flint will serve as strikers. In our own country, there is proof that prehistoric men made flints for striking a light; and at Brandon, in Suffolk, there are pits from which a specially good kind of flint is obtained, and these have

41. TINDER BOX, FLINT, STEEL, AND BRIMSTONE MATCHES

been used by the men of the Stone Age continuously till the present day; in fact, considerable numbers of fire-strikers and gun-flints are still used in savage countries.

3. One of the most vivid recollections of my childhood is of seeing the cook make tinder in the evening by burning old linen rags, and in the morning, with flint and steel, obtain the spark which, by careful

blowing, spread sufficiently to ignite the thin brimstone match from which a candle was lit and fire secured for the day.

4. The process was, however, sometimes a tedious one; and if the tinder had accidentally got damp, or if the flint were worn out, after repeated failures a light had to be obtained from a neighbour. At that time there were few savages in any part of the world but could obtain fire as easily as the most civilised of mankind.

5. At length, after the use of these rude methods for many thousand years, a great discovery was made which revolutionised the process of fire-getting. The properties of phosphorus were known to the alchemists, and it is strange that its ready ignition by friction was not made use of to obtain fire at a much earlier period.

6. It was, however, both an expensive and a dangerous material, and though about a hundred years ago it began to be made chiefly from bones, it was not used in the earliest friction matches. These were invented in 1827, or a little earlier, by Mr. John Walker, a chemist and druggist of Stockton-on-Tees, and consisted of wood splints dipped in chlorate of potash and sulphur mixed with gum, which ignited when rubbed on sandpaper.

7. Two years later, the late Sir Isaac Holden invented a similar match. About 1834, phosphorus began to be used with the other materials to cause more easy ignition, and, by 1840, these matches became so cheap as to come into general use in place of the old flint and steel. They have since spread to every part of the world, and their production constitutes one of the large manufacturing industries of England, Sweden, and many other countries.

8. Here again we have an invention that is not a modification of the older mode of obtaining fire, but a

new departure, possessing such great advantages that it rapidly led to the almost total abandonment of the old methods in every civilised country, as well as in many of the remotest and least civilised parts of the world.

9. For many thousands of years the means of obtaining fire remained almost unchanged over the whole world, till only sixty years ago, a discovery which at the time seemed of but little importance, has led to a quicker and easier process, which is so widely adopted that millions of persons in all civilised countries make use of it every day of their lives.

LESSON 13

LIGHT

"Light! Nature's resplendent robe:
Without whose vesting beauty all were wrapt
In gloom."—THOMSON.

1. Coming now to the use of fire as a light-giver, we find that an even greater change has taken place in our time.

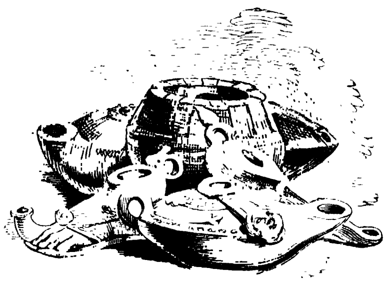
2. The first illuminants were probably torches made of resinous woods, which will give a flame for a considerable time. Then the resin exuding from many kinds of trees would be collected and applied to sticks or twigs, or to some fibrous materials tied up in bundles, such as are still used by many savage peoples,

42. A "LINK-BOY" WITH TORCH

and were used in the old baronial halls in Saxon and Norman times.

3. For outdoor lights, torches were used almost down to our own day, an indication of which is seen in the iron torch-extinguishers at the doors of many of the older London houses; while, before the introduction of gas, link-boys were as common in the streets as match-sellers are now.

4. Then came lamps, formed of small clay cups or various sea-shells of the shape of the well-known cockle, holding some melted animal fat and a fibrous wick; and, somewhat later, rush-lights and candles became common, and the story of King Alfred using them to measure time shows that they must have been very general in his day. Still later, vegetable oils were used for lamps, and wax for candles; but the three modes of obtaining illumination for domestic purposes remained entirely unchanged in principle, and very little improved, throughout the whole period of history down to the end of the eighteenth century.



43. GREEK AND ROMAN LAMPS

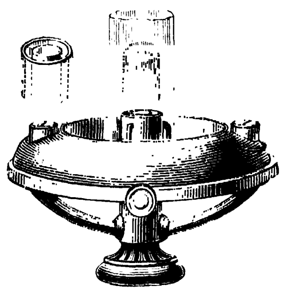
5. The Greek and Roman lamps, though in beautiful receptacles of bronze or silver, were exactly the same in principle as those of the lowest savage, and hardly better in light-giving power; and though various improvements in form were introduced, the first really important advance was made by the Argand burner.

6. This introduced a current of air into the centre

of the flame as well as outside it, and, by means of a glass chimney, a regular supply of air was kept up, and a steady light produced.

7. Although the invention was made at the end of the last century, the lamps were not sufficiently improved and cheapened to come into use till about 1830; and from that time onward many other improvements were made, chiefly dependent on the use of the cheap mineral oils, rendering lamps so inexpensive, and producing so good a light, that they are now found in the poorest cottages.

8. The only important improvement in candles is due to the use of paraffin fats instead of tallow, and of flat plaited wicks which are consumed by the flame. In my boyhood, the now extinct "snuffers" were in universal use, from the common rough iron article in the kitchen to elaborate polished steel snuffers of various makes for the parlour, with pretty metal or *papier maché* trays for them to stand in. Candles are still very largely used, being more portable and safer than most of the paraffin oil lamps. Even our lighthouses used only candles down to the early part of the present century.



44. AN ARGAND OIL-LAMP

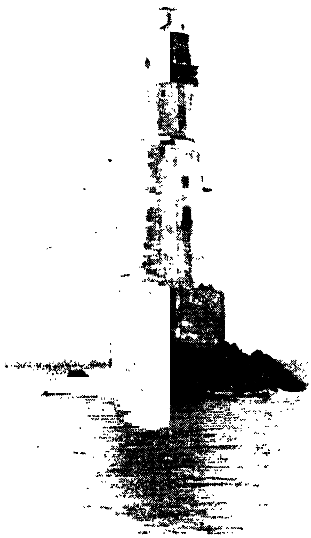
9. Both candles and lamps have afforded to our poets many striking comparisons with the shortness of human life and the contrasts of night and day. Thus Shakespeare says:—

> "My oil-dried lamp and time-bewasted light
> Shall be extinct with age and endless night."

And again :—

> "These eyes like lamps whose wasting oil is spent
> Wax dim."

While he refers to candles in no less than twenty-



45. A LIGHTHOUSE (BISHOP ROCK)

three passages, of which the following are well-known examples :—

> "How far that little candle throws his beams!
> So shines a good deed in a naughty world."

And these exquisite lines :—

> "Night's candles are burnt out, and jocund day
> Stands tiptoe on the misty mountain-tops."

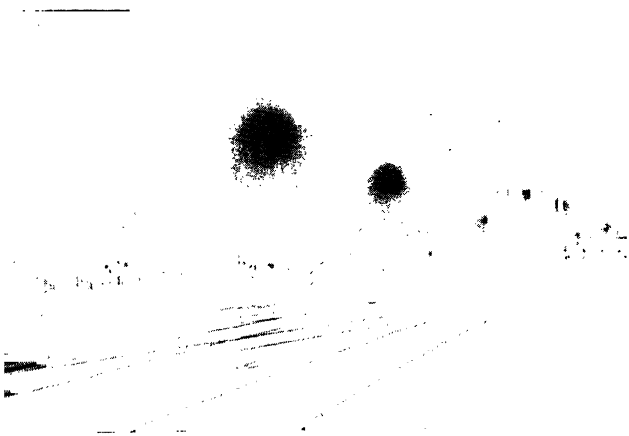
LESSON 14

GAS AND ELECTRIC LIGHTING

"Prime cheerer, light!
Of all material beings first and best."
—THOMSON.

1. A far more important and more radical change in our modes of illumination was the introduction of gas-lighting.

2. A few houses and factories were lighted with gas

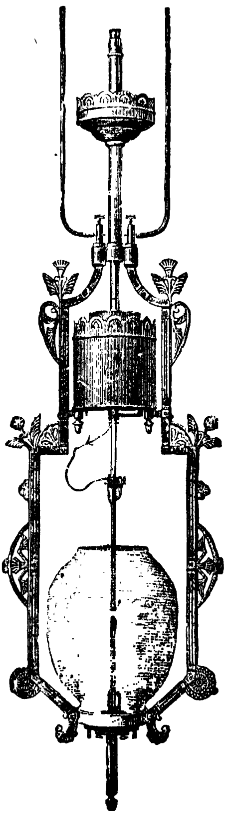


46. ELECTRIC LIGHTING (CLAPHAM JUNCTION)

at the very end of the last century, but its first application to outdoor or general purposes was in 1813, when Westminster Bridge was illuminated by it, and so successfully that its use rapidly spread to every town in the kingdom, for lighting private houses as well as streets and public buildings.

3. When it was first proposed to light London with

gas, Sir Humphry Davy, one of the greatest chemists of the time, is said to have declared it to be impracticable, both on account of the enormous size of the needful gasholders, and the great danger of explosions. These difficulties have, however, been overcome, as was the supposed insuperable difficulty of carrying sufficient coal in the case of steamships crossing the Atlantic, the impossibilities to one generation becoming the realities of the next.

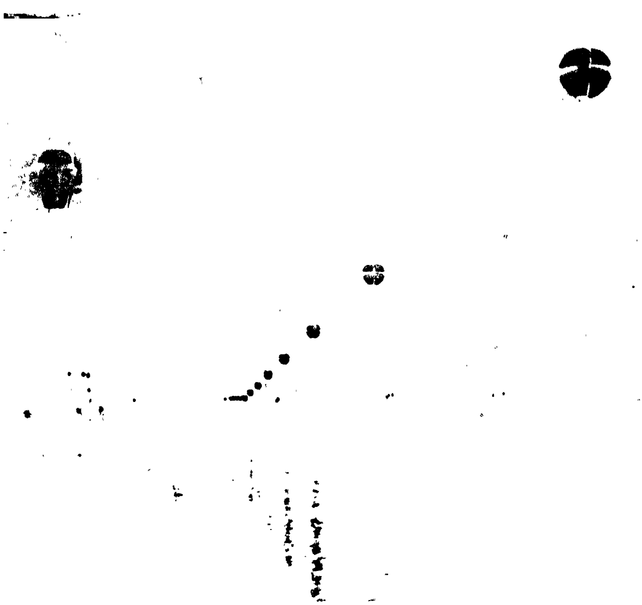


47. AN ARC LIGHT

4. Still more recent, and more completely new in principle, is the electric light, which has already attained a considerable extension for public and private illumination, while it is applicable to many purposes unattainable by other kinds of light.

5. Electric lamps are of two kinds, the arc-light and the incandescent light. The former consists of two pointed rods of carbon forming part of an electric circuit, along which a strong electric current is sent. When the carbons are slightly separated a brilliant light is produced between the points, owing to the partial vaporisation of the carbon, the vapour and the points of the carbon being intensely heated, producing a light almost equal in brilliancy to that of the sun. This is most suitable for out-of-door lighting, or for very large public buildings, such as railway stations.

6. Incandescent lamps are formed by very slender filaments of carbon, produced in a variety of ways, enclosed in small glass bulbs from which the air is exhausted. The ends of the carbon filament are joined to wires sealed into the glass, and along these wires an electric current is sent which causes the carbon to become white-hot, and to emit a soft yet brilliant light.



48. THE THAMES EMBANKMENT LIT UP BY ELECTRIC LAMPS

Several of these bulbs are usually grouped together, and give the best kind of light for shops and sitting-rooms; and when a number of these groups are disposed on the ceiling and walls of a large room, a diffused light is obtained which is very agreeable.

7. Small incandescent lamps are now used for exa-

minations of the larynx and in dentistry, and a lamp has even been introduced into the stomach, by which the condition of that organ can be examined.

8. For this last purpose, numerous ingenious arrangements have to be made to prevent possible injury, and by means of prisms at the bends of the tube the operator can inspect the interior of the organ under a brilliant light. Other internal organs have been explored in a similar manner, and many new applications in this direction will no doubt be made.

9. In illuminating submarine boats and exploring the interiors of sunken vessels, the electric lamp does what could hardly be effected by any other means.

10. We thus find, that whereas down to the end of the eighteenth century, our modes of producing and utilising light were almost exactly the same as had been in use for the preceding two or three thousand years, in the past century we have made no less than three new departures, all of which are far superior to the methods of our forefathers.

11. These are—(1) the improvement in lamps by the use of the principle of the Argand burner and chimney; (2) lighting by coal-gas; and (3) the various modes of electric lighting. The amount of advance in this one department of domestic and public illumination during the Nineteenth Century is enormous, while the electric light has opened up new fields of scientific exploration.

12. Whether we consider the novelty of the principles involved or the ingenuity displayed in their application, we cannot estimate this advance at less than that effected during the whole preceding period of human history, from that very remote epoch when fire was first taken into the service of mankind, down to the time of men now living among us.

LESSON 15

A NEW APPLICATION OF LIGHT

"O portrait, bright and wonderful!
Wrought by the sun-god's pencil true;
What grace of feature, glance of eye!
The soul itself beams out from you.

New marvel of a marvellous age!
Apelles old, whose art 'twas said
Rivalled reality, than this
Had never limned a lovelier head."[1]

1. The improvements in the mode of production of light for common use, discussed in the previous lesson, are sufficiently new and remarkable to distinguish the past century from all the ages that preceded it, but they sink into insignificance when compared with the discoveries which have been made as to the nature of light itself, its effects on various kinds of matter, leading to the art of photography, and the complex nature of the solar spectrum leading to spectrum-analysis. This group of investigations alone are sufficient to distinguish the Nineteenth Century as an epoch of the most marvellous scientific discovery.

2. Although Huygens put forward the wave-theory of light more than two hundred years ago, it was not accepted or seriously studied till the beginning of the present century, when it was revived by Thomas Young, and was shown by himself, by Fresnel, and other mathematicians, to explain all the phenomena of refraction, double-refraction, polarisation, diffraction, and interference, some of which were inexplicable on the Newtonian theory of the emission of material

[1] The above translation of the Pope's Latin verse on photography is by my friend Mr. F. T. Mott, of Leicester.

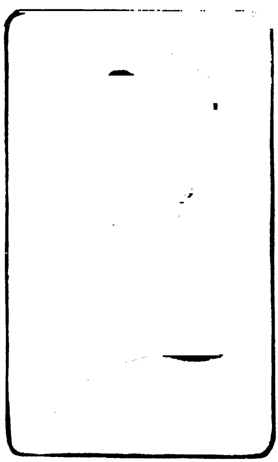
particles, which had previously been almost universally accepted. The complete establishment of the undulatory theory of light is a fact of the greatest importance, and will take a very high place among the purely scientific discoveries of the "wonderful" century.

49. THIS IS HOW WE PHOTOGRAPH TO-DAY

(*From Photo by Bassano, London*)

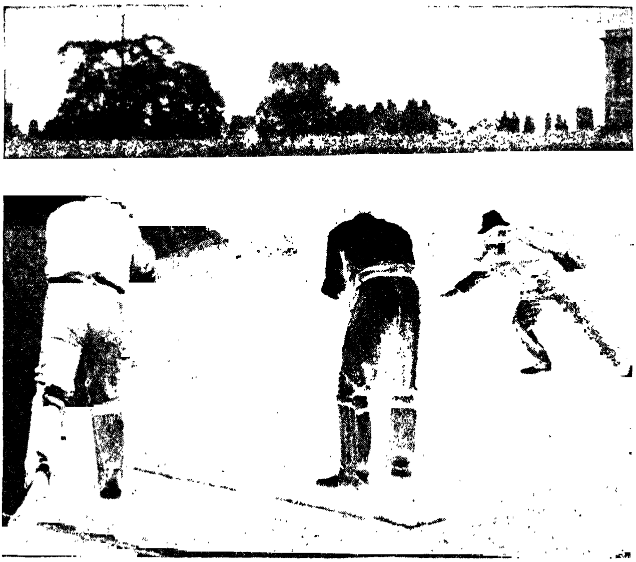
3. From a more practical point of view, however, nothing can surpass in interest and importance the discovery and continuous improvement of the photographic art, which has now reached such a development, that there is hardly any science or any branch of intellectual study that is not indebted to it. A brief sketch of its origin and progress will therefore not be uninteresting.

4. The fact that certain compounds of silver were darkened by exposure to sunlight was known to the alchemists in the sixteenth century, and this observation forms the rudiment from which the whole art has been developed. The application of this fact to the production of pictures belongs, however, wholly to our own time.



50. OUR GREAT-AUNTS HAD TO BE CONTENT WITH A SILHOUETTE

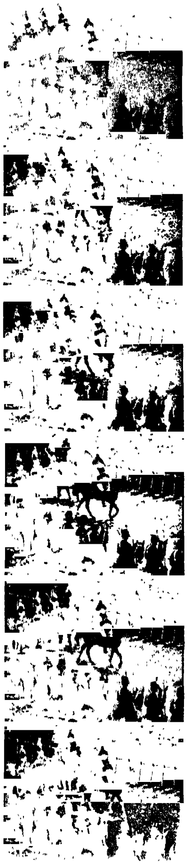
5. In the year 1802, Wedgewood described a mode of copying paintings on glass by exposure to light, but neither he nor Sir Humphry Davy could find any means of rendering the copies permanent. This was first effected in 1814 by M. Niepce of Châlon, but no important results were obtained till 1839, when



51. AN INSTANTANEOUS PHOTOGRAPH
(*From Photo by R. W. Thomas, Cheapside, London*)

Daguerre perfected the beautiful process known as the daguerreotype.

6. Permanent portraits were taken by him on silvered plates, and they were so delicate and beautiful that probably nothing in modern photography can surpass them. For several years they were the only portraits taken by the agency of light; but they were very



52. PORTION OF A MOVING OBJECT PHOTO.
THE JUBILEE PROCESSION.
Mark the gradual change in position of the men and horses.

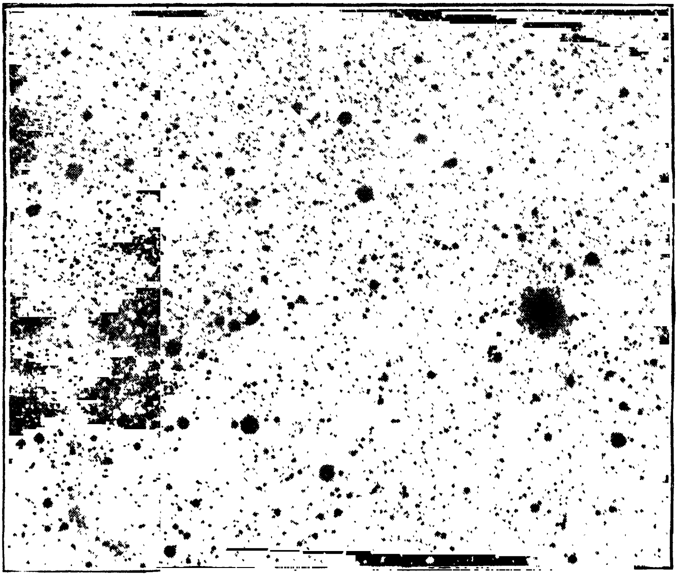
costly, and were therefore completely superseded when cheaper methods were discovered.

7. About the same time, a method was found for photographing leaves, lace, and other semi-transparent objects on paper, and rendering them permanent, but this was of comparatively little value.

8. In the year 1850, the far superior collodion film on glass was perfected, and negatives were taken in a camera-obscura, which, when placed on black velvet, or when coated with a black composition, produced pictures almost as perfect and beautiful as the daguerreotype itself, and at much less cost.

9. Soon afterwards positives were printed from the transparent negatives on suitably prepared paper, and thus was initiated the process, which, with endless modifications and improvements, is still in use. The main advance has been in the increased sensitiveness of the photographic plates, so that, first, moving crowds, then breaking waves, running horses, and other quickly moving objects were taken, while now a bullet fired from a rifle can be photographed in the air. The six pictures above, when thrown singly on a screen at intervals of $\frac{1}{30}$ second, produce the effect of continuous motion—the so-called living pictures.

LESSON 16



53. A STAR PHOTOGRAPH

PHOTOGRAPHIC "AIDS" IN SCIENCE AND ART

"Nature is made better by no mean,
But nature makes that mean."—SHAKESPEARE.

1. With such marvellous powers, photography has come to the aid of the arts and sciences in ways which would have been perfectly inconceivable to our most learned men of a century ago.

2. It furnishes the meteorologist, the physicist, and the biologist with self-registering instruments of extreme delicacy, and enables them to preserve accurate records of the most fleeting natural phenomena.

3. By means of successive photographs at short intervals of time, we are able to study the motions of the wings of birds, and thus learn something of the mechanism of flight; while even the instantaneous lightning-flash can be depicted, and we thus learn, for the first time, the exact nature of its path.

4. Perhaps the most marvellous of all its achievements is in the field of astronomy. Every increase in the size and power of the telescope has revealed to us ever more and more stars in every part of the heavens; but, by the aid of photography, stars are shown which no telescope that has been, or that probably ever will be constructed, can render visible to the human eye.

5. For by exposing the photographic plate in the focus of the object-glass for some hours, almost infinitely faint stars impress their image, and the modern photographic star-maps show us a surface densely packed with white points that seem almost as countless as the sands of the seashore.

6. Yet every one of these points represents a star in its true relative position to the visible stars nearest to it, and thus gives at one operation an amount of accurate detail which could hardly be equalled by the labour of an astronomer for months or years—even if he could render all these stars visible, which, as we have seen, he cannot do.

7. A photographic survey of the heavens is now in progress on one uniform system, which, when completed, will form a standard for future astronomers, and thus give to our successors some definite knowledge of the structure, and perhaps of the extent of the stellar universe.

8. Within the last few years, the mechanical processes by means of which photographs can now be reproduced through the printing-press have been rendered so perfect that books and periodicals are

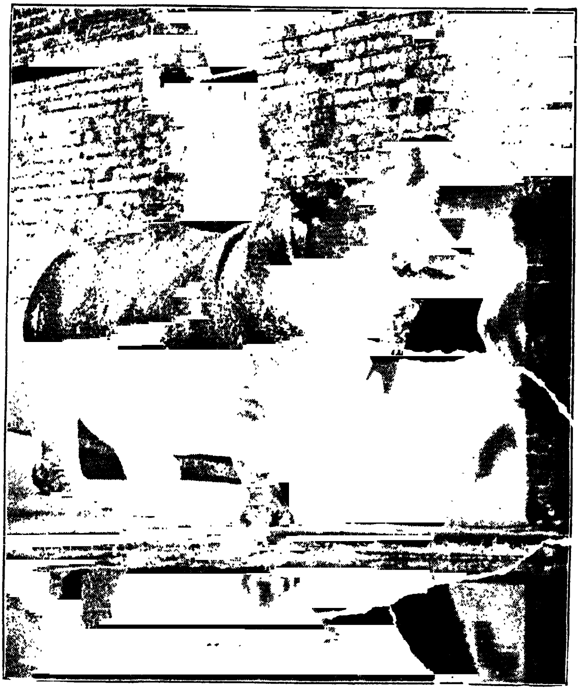
illustrated with an amount of accuracy and beauty that would have been impossible even twenty years ago, except at a prohibitive cost.

9. There are now various methods of photographic printing by means of printing-ink instead of chemicals, so as to produce an absolutely permanent picture. Such are the carbon process and the Woodburytype,

51 SPECIMEN LINE BLOCK
(Drawing from Photo by F G Stuart, Southampton)

which produce results equal in delicacy to the photographic positive itself, and which will bear magnifying in order to bring out the minutest details. But these are rather costly, though much less so than the ordinary photograph; and the numerous illustrations in books and magazines now so common are produced in a different manner, which gives a plate that can be printed as easily as an ordinary woodcut.

10. These are known as process plates, and are of two kinds. Those produced from photographs or wash drawings are technically known as *half-tone* blocks; those from pen-and-ink drawings being distinguished as *line* blocks. Both are, of course, pro-



55. SPECIMEN HALF-TONE BLOCK—MEDIUM GRAIN

(From Photo by R. W. Thomas, London)

duced by the indispensable aid of the camera; but the latter do not require the ruled screens which must be used in the reproduction of photographs or wash drawings in order to break up the more solid surfaces, and are, therefore, much less costly. The repro-

duction of pencil drawings by process is, however, a more difficult operation than even the finest photographs. Nearly all the illustrations in this book are printed from blocks of this kind; and, though often very beautiful, they will not bear magnifying like

56. SPECIMEN HALF-TONE BLOCK—FINE GRAIN

(*From a Painting by Greuze*)

photographic or Woodburytype prints. The above portrait is one of the finest kind of half-tone prints, and in its delicacy can hardly be distinguished from the original photograph of the drawing of which it is a copy.

LESSON 17

COLOUR PHOTOGRAPHY

"What find I here?
Fair Portia's counterfeit? What demi-god
Hath come so near creation."
—SHAKESPEARE.

1. It has long been the dream of photographers to discover some mode of obtaining pictures which shall reproduce all the colours of nature without the intervention of the artist's manipulation or the use of coloured glasses.

2. This was seen to be exceedingly difficult, if not impossible, because the chemical action of coloured light has no power to produce pigments of the same colour as the light itself, without which a photograph in natural colours would seem to be impossible. Nevertheless, the problem has been solved, but in a totally different manner; that is, by the principle of "interference," instead of by that of chemical action.

3. This principle was discovered by Newton, and is exemplified in the colours of the soap-bubble, and in those of mother-of-pearl and other iridescent objects. It depends on the fact that the differently coloured rays are of different wave-lengths, and the waves reflected from two surfaces half a wave-length apart neutralise each other and leave the remainder of the light coloured.

4. If, therefore, each differently coloured ray of light can be made to produce a corresponding minute wave-structure in a photographic film, then each part of the film will reflect only light of that particular wave-length, and therefore of that particular colour, that produced it. This has actually been done by Professor Lipp-

mann, of Paris, who published his method in 1891; and in a lecture before the Royal Society in April 1896, he fully described it and exhibited many beautiful specimens.[1]

5. The method is as follows:- A sensitive film, of some of the usual salts of silver in albumen or gelatine, is used, but with much less silver than usual, so as to leave the film quite transparent. It must also be perfectly homogeneous, since any granular structure would interfere with the result.

6. This film on glass must be placed in a frame so constructed that at the back of it there is a shallow cell that can be filled with mercury which is in contact with the film. It is then exposed in the usual way, but much longer than for an ordinary photograph, so that the light-waves have time to produce the required effect. The light of each particular tint being reflected by the mercury, meets the incoming light and produces a set of *standing* waves—that is, of waves surging up and down, each in a fixed plane.

7. The result is, that the metallic particles in the film become assorted and stratified by this continued wave-action, the distance apart of the strata being determined by the wave-length of the particular coloured light—for the violet rays about eight millionths of an inch; so that in a film of ordinary thickness there would be about five hundred of these strata of thinly-scattered metallic particles.

8. The quantity of silver used being very small, when the film is developed and fixed in the usual way the result is not a light-and-shade negative, but a nearly transparent film, which nevertheless reflects a sufficient amount of light to produce a naturally coloured picture.

[1] This lecture is reported in *Nature*, vol. liii. p. 617.

9. The principle is the same for the light-waves as that of the telephone for sound-waves. The voice sets up vibrations in the transmitting diaphragm, which, by means of an electric current, are so exactly reproduced in the receiving diaphragm as to give out the same succession of sounds.

10. An even more striking, and perhaps closer analogy is that of the phonograph, where the vibrations of the diaphragm are permanently registered on a wax cylinder, which, at any future time, can be made to set up the same vibrations of the air, and thus reproduce the same succession of sounds, whether words or musical notes. So the rays of every colour and tint that fall upon the plate throw the deposited silver within the film into minute strata which permanently reflect light of the very same wave-length, and therefore of the very same colour, as that which produced them.

11. The effects are said to be most beautiful, the only fault being that the colours are more brilliant than in nature, just as they are when viewed in the camera itself. This, however, may perhaps be remedied (if it require remedying) by the use of a slightly opaque varnish.

12. The comparatively little attention that has been given to this beautiful and scientifically perfect process is no doubt due to the fact that it is rather expensive, and that the pictures cannot, at present, be multiplied rapidly. But for that very reason it ought to be especially attractive to amateurs, who would have the pleasure of obtaining exquisite pictures which will not become commonplace by indefinite reproduction.

13. All other modes of producing colour-photographs depend upon the use of coloured screens or glasses, and are therefore not due to photography alone. In Ive's trichromic method three photographs are taken

through glasses of the three primitive colours, and these are viewed by means of similarly coloured light, and combined by mirrors into one picture. The result is a coloured view more or less closely resembling nature, but only to be seen by means of a rather costly apparatus. Better and far more useful pictures are produced by the Swiss process of colour-printing now so common, which are often both natural and artistic in a high degree. The coloured plate which forms our frontispiece is an example of this process. It will be again referred to in Lesson 47, as it serves to illustrate one of the most remarkable phenomena due to the action of ice in the Glacial Epoch which is there described.

LESSON 18

PHOTOGRAPHY AND ART

"Oh, how much more doth beauty beauteous seem,
By that sweet ornament which truth doth give."
—SHAKESPEARE.

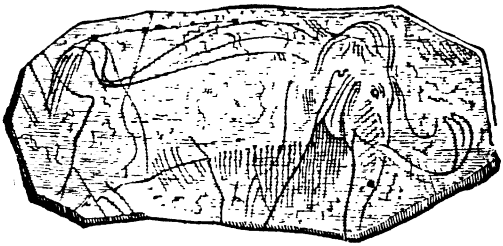
1. The brief sketch of the rise and progress of photography now given illustrates the same fact which we have already dwelt upon in the case of other discoveries.

2. This beautiful and wonderful art, which already plays an important part in the daily life and enjoyment of all civilised people, and which has extended the bounds of human knowledge into the remotest depths of the starry universe, is not an improvement of, or development from, anything that went before it, but is a totally new departure.

3. From that early period when the men of the Stone Age rudely outlined the mammoth and the reindeer on stone or ivory, the only means of representing men and animals, natural scenery, or the great events

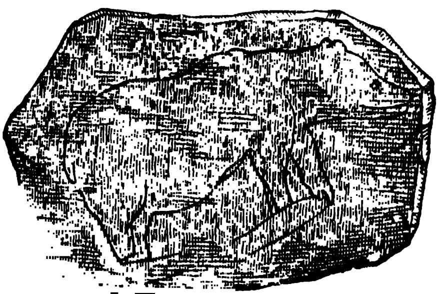
of human history, had been through the art of the painter or the sculptor.

4. It is true that the highest Greek, or Mediæval, or modern art, cannot be equalled by the productions of



57. *Drawing of a Mammoth from the Cave of La Madelaine*
The earliest-known Picture in the World

the photographic camera; but great artists are few and far between, and the ordinary, or even the talented draughtsman can give us only suggestions of what he



Drawing of Cave-Bear, from the Cave of Massat

58. STONE-AGE DRAWINGS ON IVORY

sees, so modified by his peculiar mannerism as often to result in a mere caricature of the truth.

5. Should some historian in Japan study the charac-

teristics of English ladies at two not remote epochs, as represented, say, by Frith and by Du Maurier, he would be driven to the conclusion that there had been a complete change of type, due to the introduction of some foreign race, in the interval between the works of these two artists. From such errors as this we shall be saved by photography; and our descendants in the middle of the coming century will be able to see how much, and what kind, of change really does occur from age to age.

6. The importance of this is well seen by comparing any of the early works on Ethnology, illustrated by portraits intended to represent the different "types of mankind," with recent volumes which give us copies of actual photographs of the same types; when we shall see how untrue to nature are the former, due probably to the artist having delineated those extreme forms, either of ugliness or of beauty, that most attracted his attention, and to his having exaggerated even these.

7. Thus only can we account for the pictures in some old voyages, showing an English sailor and a Patagonian as a dwarf beside a giant; and for the statement by the historian of Magellan's voyage, that their tallest sailor only came up to the waist of the first man they met. It is now known that the average height of Patagonian men is about five feet ten inches, or five feet eleven inches, and none have been found to exceed six feet four inches. Photography would have saved us from such an error as this. (See plate.)

8. There will always be work for good artists, especially in the domain of colour and of historical design; but the humblest photographer is now able to preserve for us and for future generations minutely accurate records of scenes in distant lands, of the ruins

A Sailor giving a Patagonian Woman a Biscuit for her Child.

59. (*From "The Modern Traveller,"* 1776)

of ancient temples, which are sometimes the only record of vanished races, and of animals or plants that are rapidly disappearing through the agency of man. And, what is still more important they can preserve for us the forms and faces of the many lower races which are

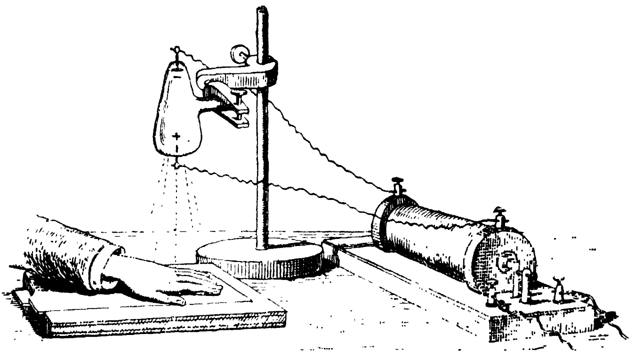
60. NATIVE OF THE TONGA ISLANDS

slowly but surely dying out before the rude incursions of our imperfect civilisation.

9. That such a new and important art as photography should have had its birth, and have come to

maturity, so closely coincident with the other great discoveries of the century already alluded to, is surely a very marvellous fact, and one which will seem more extraordinary to the future historian than it does to ourselves, who have witnessed the whole process of its growth and development.

LESSON 19



61. THE "X" RAYS AT WORK

THE "X" RAYS

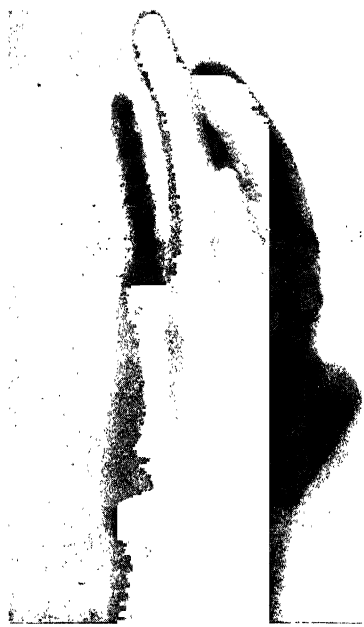
"Dark needs no candles now, for dark is light."
—SHAKESPEARE.

1. The most recent of all the discoveries in connection with light and photography, and one which extends our powers of vision in a direction and to an extent the limits of which cannot yet be guessed at, is that peculiar form of radiation termed the X or Röntgen rays, from Professor Röntgen of Würzburg, who was the first to investigate their properties and make practical applications of them.

2. These rays are produced by an electrical current

sent through a vacuum tube, the sides of which, under the action of the current, become intensely luminous. If the tube is now enclosed in black cardboard, though no visible rays pass, yet radiations are emitted which excite luminosity in fluorescent substances.

3. But this radiation has very different properties from ordinary light, inasmuch as the substances which are opaque or transparent to it are not the same as those to which we usually apply the terms, but often the very contrary.



62. A RÖNTGEN RAY PHOTO, SHOWING BONES OF HAND

(From a Photo by F G. Stuart, Southampton)

4. Paper, for instance, is so transparent that the rays will pass through a book of a thousand pages, or through two packs of cards. both of which would be absolutely opaque to the most brilliant ordinary light. Aluminium, tin, and glass of the same thickness are all transparent, but they keep out a portion of the rays, whereas platinum and lead are quite opaque.

5. To these rays, aluminium is two hundred times as transparent as platinum. Wood, carbon, leather, and slate are much more transparent to the "X" rays

than is glass, some kinds of glass being almost opaque, though quite transparent to ordinary light.

6. Flesh and skin are transparent in moderate

63. FINDING A BULLET WITH THE X-RAY APPARATUS AT A MILITARY HOSPITAL

(From a Drawing by Mr. René Bull)

thicknesses, while bone is opaque. If, therefore, the rays are passed through the hand, the bones cast a shadow, though an invisible one; and as, most fortu-

nately, the rays act upon photographic plates almost like ordinary light, hands or other parts of the body can be photographed by their shadows, and will show the bones by a much darker tint.

7. From this property comes their use in surgery, to detect the exact position of bullets or other objects embedded in the flesh or bone. A needle which penetrated the knee-joint and then broke off, leaving a portion embedded which set up inflammation, and might have necessitated the loss of the limb, was shown so accurately that a surgeon cut down to it and got it out without difficulty.

8. An exceptional property of these rays is, that they are not either refracted or reflected as are ordinary light and heat. Hence it is only the shadow that can be photographed.

9. Another curious result of this is that they can pass through a powder as easily as through a solid; whereas ordinary light cannot pass through powdered glass or ice, owing to the innumerable reflections and refractions, which soon absorb all the rays except those reflected from a very thin surface layer. Proportionate thicknesses of aluminium or zinc, whether in the solid plate or in powder, are equally transparent to these singular rays.

10. So much is already popularly known on this subject that it is not necessary to go into further details here. But this new form of radiant energy opens up so many possibilities, both as to its own nature and as to the illimitable field of research into the properties and powers of the mysterious ether, that it forms a fitting dramatic climax to the scientific discoveries of the century in the domain of light.

LESSON 20

ANOTHER WONDERFUL APPLICATION OF LIGHT

"Hushed be all earthly rhymes!
List to those spheral chimes
That echo down the singing vaults of night.
The quivering impulse runs
From the exultant suns,
Circling in endless harmonies of light."
—F. T. MOTT.

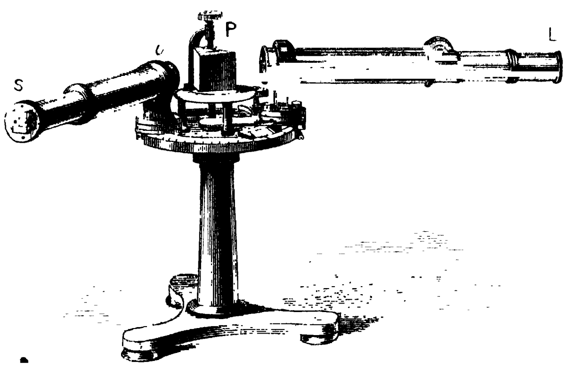
1. Among the numerous scientific discoveries of the past century, we must give a very high, perhaps even the highest, place to spectrum analysis, not only because it has completely solved the problem of the true nature and cause of the various spectra produced by different kinds of light, but because it has given us a perfectly new engine of research, by which we are enabled to penetrate into the remotest depths of space, and learn something of the nature and the motions of the constituent bodies of the stellar universe. Through its means we have acquired what are really the equivalents of new senses, which give us knowledge that before seemed absolutely and for ever unattainable by man.

2. The solar spectrum is that coloured band produced by allowing a sunbeam to pass through a prism, and a portion of it is given by the dewdrop or the crystal when the sun shines upon them; while the complete band is produced by the numerous raindrops, the coloured rays from which form the rainbow.

3. Newton examined the colours of the spectrum very carefully, and explained them on the theory that light of different colours has different refrangibilities—

or, as we now say, different wave-lengths. He also showed that a similar set of colours can be produced by the interference of rays when reflected from the two surfaces of very thin plates, as in the case of what are termed Newton's rings and in the iridescent colours of thin films of oil on water, of soap bubbles, and many other substances.

4. These colour-phenomena, although very interesting in themselves, and giving us more correct ideas of the nature of colour in the objects around us, did not



64. THE SPECTROSCOPE

lead to anything further. But in 1802, the celebrated chemist, Dr. Wollaston, made the remarkable discovery that the solar spectrum, when closely examined, is crossed by very numerous black lines of various thicknesses, and at irregular distances from each other.

5. Later, in 1817, these lines were carefully measured and mapped by the Bavarian optician, Fraunhofer, but their meaning remained an unsolved problem till about the year 1860, when the German physicist, Kirchhoff, discovered the secret, and opened

up to chemists and astronomers a new engine of research whose powers are probably not yet exhausted.

6. It was already known that the various chemical elements, when heated to incandescence, produce spectra consisting of a group of coloured bands, and it had been noticed that some of these bands, as the yellow band of sodium, corresponded in position with a certain black line (D) in the solar spectrum (Fig. 65).

7. Kirchhoff's discovery consisted in showing that, when the light from an incandescent body passes through the same substance in a state of vapour, much of it is absorbed, and the coloured bands become replaced by black lines. The black lines in the solar

65. SOLAR SPECTRUM

spectrum are due, on this theory, to the light from the incandescent body of the sun being partially absorbed in passing through the vapours which surround it.

8. This theory led to a careful examination of the spectra of all the known elements, and on comparing them with the solar spectrum, it was found that in many cases the coloured bands of the elements corresponded exactly in position with certain groups of black lines in the solar spectrum. Thus hydrogen, sodium, iron, magnesium, copper, zinc, calcium, and many other elements have been proved to exist in the sun. The curve in Fig. 65 shows variations of heat.

9. Some outstanding solar lines, which did not correspond to any known terrestrial element, were

supposed to indicate an element peculiar to the sun, which was therefore named Helium. Quite recently this element has been discovered in a rare mineral, and its coloured spectrum is found to correspond exactly to the dark lines in the solar spectrum on which it was founded, thus adding a final proof of the correctness of the theory, and affording a striking example of its value as an instrument of research.

10. Spectrum analysis is of great use to the chemist. By its means, Sir William Crookes discovered the metal thallium in 1861, while examining a deposit from a flue where iron pyrites had been burned in the manufacture of sulphuric acid. The vapour from this deposit, when observed in the spectroscope, showed a brilliant green line never seen before. Several other new elements have since been discovered by the same means, some in the water of mineral springs, others in various rare minerals.

LESSON 21

STAR SPECTRA (1)

"Far beyond Orion bright
  Cloud on cloud the star-haze lies;
Million years bear down the light
  Earthward from those ghost-like eyes."

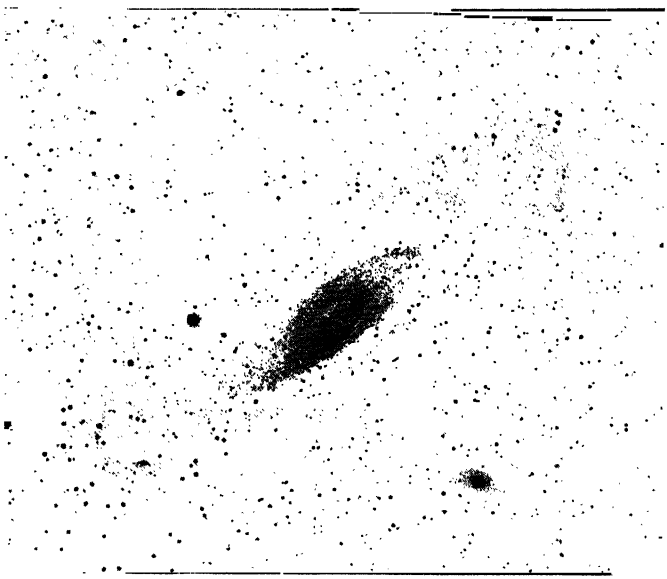
—F. T. PALGRAVE.

1. The immediate effect of the application of the spectroscope to the stars was very striking. The supposition that they were suns became a certainty, since they gave spectra similar in character, and often very closely resembling in detail, that of our sun.

2. Aldebaran, for instance, is one of the most sun-like stars, being yellow in colour and possessing lines which indicate most of the elements found in the sun.

White stars, such as Sirius and Vega, show hydrogen lines only; and these are supposed to be hotter than our sun, and in an earlier stage of development, while red stars are supposed to be cooling. Other explanations of these facts have, however, been suggested.

3. Much information has also been obtained as to the nature of the nebulæ. Sir William Herschel



66. PHOTOGRAPH OF THE GREAT NEBULA IN ANDROMEDA

supposed that they were all really star-clusters, but so enormously remote that even the most powerful telescopes could not render visible the stars composing them. Later observations have shown that many of them do consist of stars, or star-dust, as it has been called; and this seemed to support the theory that all were so composed, including the Milky Way.

4. A study of the distribution of stars and nebulæ by Proctor and others led, however, to the conclusion that they were often really connected, and that nebulæ were not, on the average, more distant than stars; and this view has been confirmed by the spectroscope, which has shown them often to consist of glowing gas; and this is especially the characteristic of all those situated in or near the Milky Way.

5. The first great result of spectrum analysis has thus been to demonstrate the real nature of many stars and nebulæ, to determine some of the elements of which they are formed, and to give us some indications of the changes they have undergone, and thus help us towards a general theory of the development of the stellar universe.

6. Marvellous as is this extension of our knowledge of objects so distant that our largest telescopes are powerless to show them as more than points of light, it is only a part, perhaps only a small part, of what the spectroscope has already done, or may yet do, for astronomy.

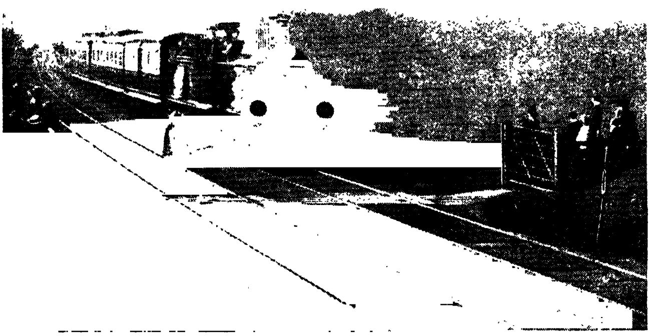
7. By a most refined series of observations, it has enabled us to detect and measure certain motions of the stars, which seemed to be wholly beyond our grasp; and also to demonstrate the existence of celestial bodies which could be detected in no other way.

8. In order to understand how this is possible, we have to make use of the wave-theory of light; and the analogy of other wave-motions will enable us better to grasp the principle on which these calculations depend.

9. If, on a nearly calm day, we count the waves that pass by an anchored steam-boat in one minute, and then travel in the direction the waves come from, we shall find that a larger number pass us in the same time.

10. Again, if we are standing near a railway, and an engine comes towards us whistling, we shall notice that it changes its tone as it passes us; and as it recedes the sound will be very different, although the engine is at the same distance from us as when it was approaching.

11. Yet the sound does not change to the ear of the engine-driver, the cause of the change being that the sound-waves reach us in quicker succession as the



67. INSTANTANEOUS PHOTOGRAPH OF THE QUEEN'S TRAIN
(By C. P. Castine, Swanley)

source of the waves is approaching us than when it is retreating from us.

12. Now just as the pitch of a note depends upon the rapidity with which the air-vibrations reach our ear, so does the colour of a particular part of the spectrum depend upon the rapidity with which the ethereal waves which produce colour reach our eyes; and as this rapidity is greater when the source of the light is approaching than when it is receding from us.

a slight shifting of the position of the dark lines will occur, as compared with their position in the spectrum of the sun or of any stationary source of light, if there is any motion sufficient in amount to produce a perceptible shift.

13. On experimenting with a powerful spectroscope constructed for the purpose, Sir William Huggins, in 1868, found that such a change did occur in the case of many stars, and that their rate of motion towards us or away from us—termed the radial motion—could be calculated. As the actual distance of some of these stars has been measured, and their change of position annually (their proper motion) determined, the additional factor of the amount of motion in the direction of our line of sight completes the data required to fix their true line of motion among the other stars. A further account of this interesting discovery will be given in the next lesson.

LESSON 22

STAR SPECTRA (2)

> "The sky
> Spreads like an ocean hung on high,
> Bespangled with those isles of light
> So wildly, spiritually bright."
>
> -LORD BYRON.

1. The method of research described in the last lesson has now been applied to many double stars with great success, observations of their spectra showing that, in some cases, they move one towards and one away from us, as they must do if they are revolving around their common centre of gravity

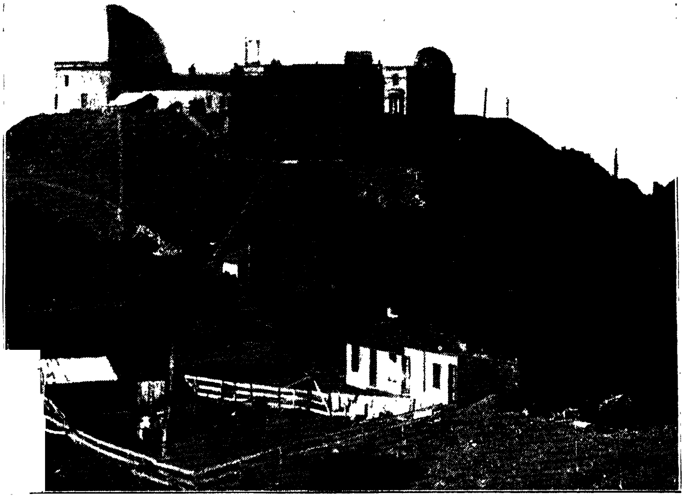
in an ellipse whose plane lies approximately in our direction.

2. It has also brought to light the interesting fact that some stars, which appear single in the most powerful telescopes, are really double, since their spectra show a shifting of spectrum lines, which after a considerable time changes to an opposite direction; and by the period occupied in the complete change of direction the time of rotation of the component stars can be determined, although one of the components has never been seen.

3. By this means, the variable star Algol has been proved to have a dark companion which partially eclipses it every sixty-nine hours; and both Sirius and Procyon have been shown to have dark or less visible companions, that of Sirius being really just visible in the very best telescopes. The unusual motions of Sirius have been long known, and were supposed to be due to the presence of a companion, which has now been shown to be the true explanation.

4. The accuracy of this method under favourable conditions is very great, as has been proved by those cases in which we have independent means of calculating the real motion, as we have in the case of the inner planets.

5. The motion of Venus towards or away from us can be calculated with great accuracy for any period, being a resultant of the combined motions of the planet and of our earth in their respective orbits. These radial motions of Venus were determined at the Lick Observatory (in California) in August and September 1890, by spectroscopic observations, and also by calculation, to be as follows:—



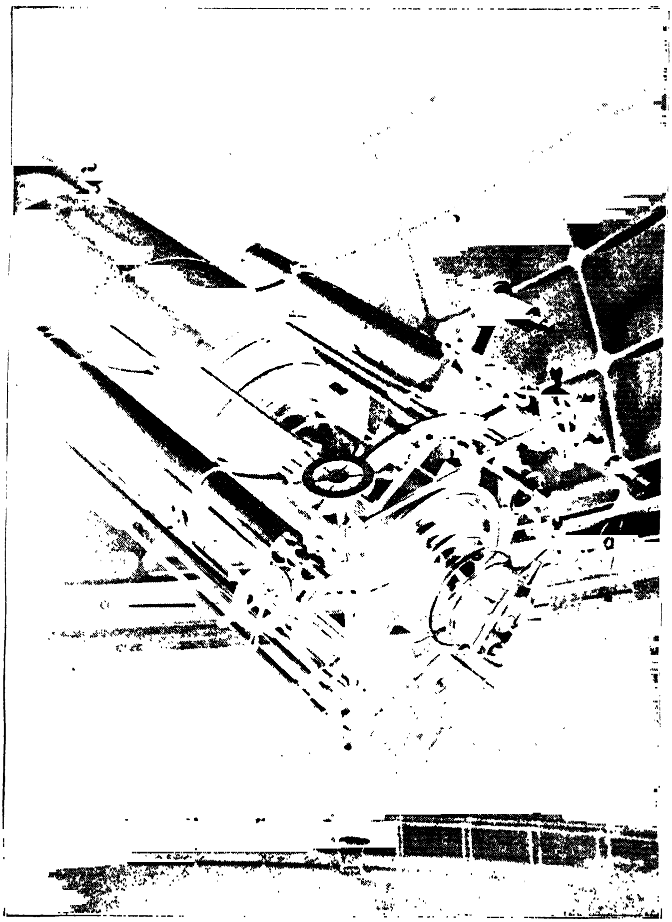
68. THE LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA

BY OBSERVATION.			BY CALCULATION.	
Aug. 16th.	—7·3	miles per second.	—8·1	miles per second.
,, 22nd.	—8·9	,,	—8·2	,,
,, 30th.	—7·3	,,	—8·3	,,
Sept. 3rd.	—8·3	,,	—8·3	,,
,, 4th.	—8·2	,,	—8·3	,,

showing that the maximum error was only one mile per second, while the mean error was about a quarter of a mile.

6. Owing to the greater difficulty in observing the spectra of stars, the accuracy in their case is probably not quite so great. This has been tested by observations of the same star at times when the earth's motion in its orbit is towards or away from the star, whose apparent radial velocity is, therefore, increased or diminished by a known amount. Observations of this kind were made by Dr. Vogel, Director of the Astro-

physical Observatory at Potsdam, showing, in the case of three stars, of which ten observations were taken, a mean error of about two miles per second.



69. THE EYE-END OF THE GREAT LICK REFRACTOR

7. The same observer, from his study of the spectra

of the variable star Algol, has been able to determine that both the visible star and its dark companion are somewhat larger than our sun, though of less density; that their centres are 3,230,000 miles apart, and that they move in their orbits at rates of 55 and 26 miles per second respectively; and this information, it must be remembered, has been gained as to objects the light of which takes about forty-seven years to reach us!

8. So striking are these results, and so rapid has been the increase in the delicacy and trustworthiness of the observations, that the President of the Royal Astronomical Society, in an address delivered in 1893, contemplated the possibility that, by still further refinements in the application of the spectroscope, the most accurate measures of the rate of motion of our earth in its orbit, and, therefore, of the distance of the sun, might be deduced from observations of stars which are themselves so remote as to be beyond our powers of measurement.

9. It is an interesting fact that, so recently as the year 1842, the French mathematician and philosopher, Comte, declared that all study of the fixed stars was waste of time, because their distance was so great that we could *never* learn anything about them—a striking illustration of the complete novelty, no less than of the wonderful possibilities, of this marvellous engine of research.

10. Not only is it a wholly new departure from anything known or even imagined before, but it is able to give us a large and varied amount of knowledge of that portion of the visible universe which has hitherto been the least known, and which seemed to be the most hopelessly unapproachable. On every ground, therefore, we must place the discovery and

applications of spectrum analysis as deserving of the highest place among the numerous great scientific achievements of the nineteenth century.[1]

LESSON 23

DISCOVERIES IN PHYSICS

(i.) HEAT A MODE OF MOTION

"For the world was built in order,
And the atoms march in tune."
—EMERSON.

1. The theoretical discoveries in the domain of physics (besides those already referred to) have been very numerous, but only a few of them have enough generality or have become sufficiently popular to require notice in this volume.

2. Two of these discoveries, however, stand above the general level as important contributions to our knowledge of the material universe. These are (1) the determination of the mechanical equivalent of heat, leading to the general theory of the conservation of energy, and (2) the molecular theory of gases.

3. Down to the beginning of the Nineteenth Century, heat was considered to be a form of matter, termed caloric or phlogiston. The presence of phlogiston was supposed to render substances combustible, but when the chemical theory of combustion was discovered by

[1] Teachers and students will find an admirable account of the application of the spectroscope to the heavens in an article on "The New Astronomy" in the *Nineteenth Century* for June 1897. It is written by Sir William Huggins, the greater part of whose life has been devoted to this branch of the science, in which he was one of the earliest and most successful observers and discoverers. The subject is also treated at some length in the new and enlarged edition of my *Wonderful Century.*

Lavoisier, phlogiston, as the cause of combustion, disappeared, although caloric, as the material basis of heat, still held its ground.

4. Close to the end of the eighteenth century, Count Rumford showed that, in boring a brass cannon, the heat developed in $2\frac{1}{2}$ hours was sufficient to raise $26\frac{1}{2}$ lbs. of water from the freezing to the boiling point. But during the operation the metal had lost no weight or undergone any other change; and as the production of heat by this process appeared to be unlimited, he concluded that heat could not be matter, but merely a kind of motion set up in the particles of matter by the force exerted.

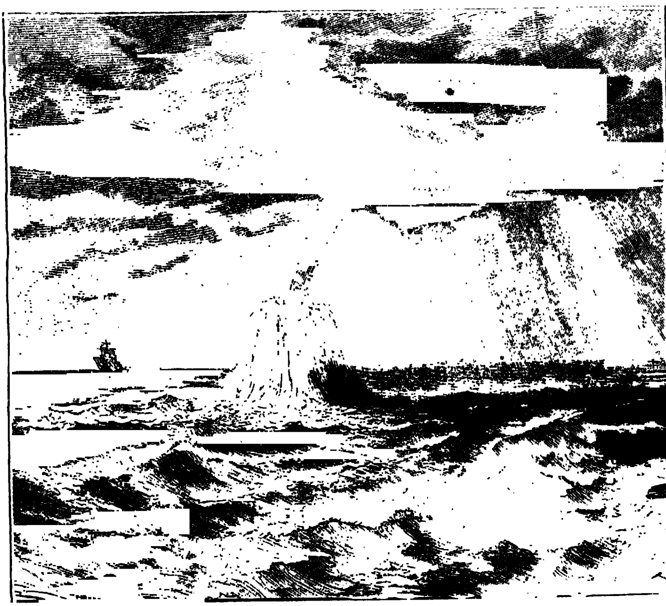
5. Bacon and Locke had expressed similar ideas long before; and, later, Sir Humphry Davy showed that by rubbing together two pieces of ice at a temperature below the freezing-point, sufficient heat was produced to partially melt them; while other observers found that to shake water in a bottle raised its temperature, and that percussion or compression, as had been long known, produced a considerable amount of heat.

6. These various facts led to the conclusion that there was a mechanical equivalent of heat—that is, that a certain amount of force exerted or work done would produce a corresponding amount of heat; and Joule was the first to determine this accurately by a number of ingenious experiments. The result was found to be, that a pound of water can be raised 1° C. by an amount of work equal to that required to raise one pound to the height of 1392 feet, or 1392 lbs. one foot.

7. Various experiments with different materials were found always to lead to the same result, and thus the final blow was given to the material theory of heat,

which was thenceforth held to be *a mode of motion of the molecules of bodies.*

8. These conclusions led to the more general law of the conservation of energy, which implies that in any limited system of bodies, whether a steam-engine or the solar system, no change can occur in the total amount of the energy it contains unless fresh energy



70. A WATERSPOUT AT SEA

comes to it from without, or is lost by transmission to bodies outside it. But as, in the case of the sun, some heat is certainly lost by radiation into space, unless an equal amount comes in from the stellar universe, the system must be cooling, and in sufficient time would lose all its heat, and therefore much of its energy.

9. The chief use of the principle is to teach us what becomes of force expended without any apparent result, as when a ball falls to the ground and comes to rest. We now know that the energy of the falling ball is converted into heat, which, if it could be all preserved and utilised, would again raise the ball to the height from which it fell. It also enables us to trace most of the energy around us, whether of wind or water or of living animals, to the heat and light of the sun.

10. Wind is caused by inequalities of the sun's heat on the earth; all water power is due to evaporation by the sun's heat, which thus transfers the water from the ocean surface to the clouds, and thence to the mountains, producing rivers; solar heat alone gives power to plants to absorb carbonic acid and build up their tissues, and the energy thus locked up is again liberated when wood is burnt or during the muscular action of the animals which have fed directly or indirectly on the plants. The inventor of the locomotive, George Stephenson, used to say that it was the sun's heat which drove his engines and their loads thirty miles an hour, showing that he had independently arrived at the source of all terrestrial energy.

11. This great principle enables us to realise the absolute interdependence of all the forces of nature. It teaches us that there is no origination of force upon the earth, but that all energy either now comes to us from the sun or was originated in the sun before our earth separated from it; and we are thus led to the conclusion that all work, all motion, every manifestation of power we see around us, are alike the effects of heat or of other radiant forces allied to it. This conclusion we shall find is still further enforced by the next great discovery we have to notice.

71. A MOUNTAIN STORM

LESSON 24

(ii.) THE MOLECULAR THEORY OF GASES

"Science has unravelled the web in which all things are involved, and has found its texture even more wonderful and exquisite than she could have thought."—WHEWELL.

1. The very remarkable properties of gases, their apparently unlimited elasticity and indefinite powers of expansion, were very difficult to explain on any theory of their molecules being subject to such attractive and repulsive forces as seem to exist in other states of matter.

2. A consideration of these properties, together with the power of diffusion, by which gases of very different densities form a perfect mixture when in contact, and the fact that by the application of heat almost all liquids and many solids can be changed into gases, led to the conception that they owed their peculiar properties to their molecules being in a state of intensely rapid motion in all directions.

3. On this theory the molecules are very far apart in proportion to their size, and are continually coming in contact with each other. Owing to their perfect elasticity, they rebound without loss of motion or energy, and their continual impact against the sides of the vessel containing them is what gives to gases their great expansive force.

4. From a study of these various properties, it has been calculated that, at ordinary temperatures, there are some hundred of trillions of molecules in a cubic inch of gas, and that these collide with each other eight thousand millions of times in a second. The average length of the path between two collisions of

a molecule is less than the two hundred thousandth of an inch; yet this small length is supposed to be at least a hundred times as great as the diameter of each molecule.

5. From the fact that all gases expand with heat and contract with cold, it is concluded that the ether-vibrations we term heat are the cause of the rapid motions of the gaseous molecules, and that, if heat was entirely absent, the motion would cease, and ordinary cohesive attraction coming into play, the molecules would fall together and form a liquid or a solid.

6. As a matter of fact, by intense cold, combined with pressure, all gases can be liquefied or solidified; and as, on the other hand, all the solid elements can be liquefied or vaporised by the intense heat of the electric furnace, we conclude that all matter when entirely deprived of heat is solid, and with sufficient heat becomes gaseous.

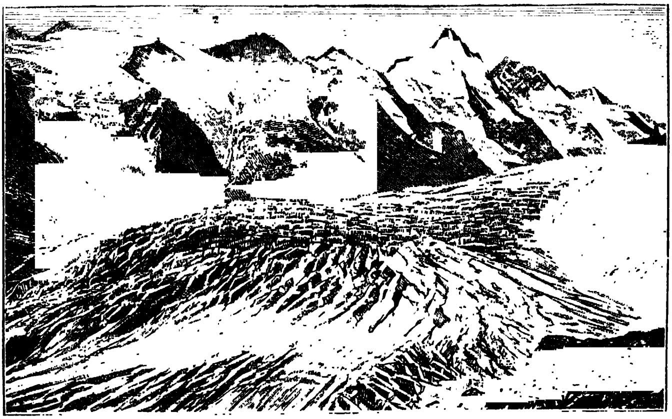
7. As might be expected from these varied phenomena, it has been found that there is no such sharp line of distinction between the various states of matter as is popularly supposed, some of the properties which are characteristic of matter in one state being present in a less degree in other states.

8. Viscous bodies, for example, often present phenomena characteristic of both solids and fluids. Sealing-wax, pitch, and ice are all brittle at low temperatures, resembling in this respect such solids as glass and stone; but they are at the very same time fluid, if time enough is allowed to exhibit the phenomenon.

9. This is seen in the motion of glaciers, which move in every respect like true fluids, even to the middle of the stream flowing quicker than the sides

and the top than the bottom. Eddies and whirls occur in glaciers as in rivers, and also upward and downward motion, so that rocks torn off the glacier floor may be carried upwards and deposited on surfaces hundreds of feet above their place of origin.

10. These properties can be shown to exist by experiment even on a small scale. A slab of ice supported on its two ends will become gradually curved, and the curvature may be increased to any



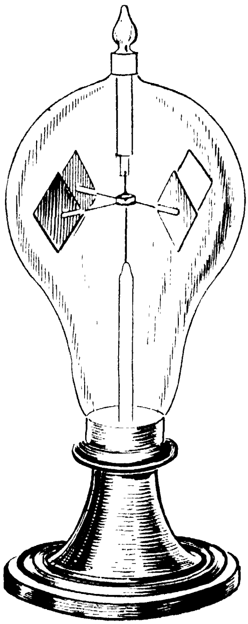
72. A GLACIER

desired extent if force is applied for a sufficient time. Models of glaciers in cobbler's wax, which is brittle at ordinary temperatures, exhibit all the phenomena of true glacier-motion, and serve to demonstrate the upward motions above referred to, which have been so often denied. Most metals exhibit similar phenomena under suitable conditions, and lead can be made actually to flow out of a hole under pressure.

11. An experimental illustration of the molecular theory of gases is afforded by the radiometer, a

little instrument which may be seen in almost every optician's window.

12. It was invented by Sir William Crookes in 1873, and consists of an exceedingly delicate windmill, formed of four very slender arms supporting thin metal or pith discs, one side of which is blackened, the whole turning on a fine central point, so as to revolve with hardly any friction. The little machine is enclosed in a glass bulb from which nearly all the air has been extracted; and when exposed to the sun, or even to diffused daylight, the discs revolve with considerable speed.



73. THE RADIOMETER

13. At first this motion was supposed to be caused by the direct impact of the rays of light, the almost complete vacuum only serving to diminish friction; but the explanation now generally adopted is, that the black surfaces of the vanes, absorbing heat, become slightly warmer than the white surfaces, and this greater warmth is communicated to the air-molecules, and causes them to rebound with greater rapidity from the dark surfaces, and back again from the glass of the vessel, and the reaction being all in one direction, causes the arms to revolve.

14. The near approach to a vacuum is necessary, both to diminish resistance, and by greatly reducing the number of molecules in the vessel, to allow the very small differential action to produce a sensible

effect. Sir William Crookes has found that there is a degree of rarefaction where the action is at a maximum, and that when a nearer approach to a perfect vacuum is attained the motion rapidly diminishes. A proof is thus given of the correctness of the molecular theory of gases.

LESSON 25

(iii.) HEAT THE SOURCE OF ALL CHANGE

"Bright-flaming, heatful fire,
The source of motion."
—SYLVESTER'S DU BARTAS, *Divine Weekes and Workes.*

1. One of the most characteristic properties of gases and liquids is that of readily mixing together when placed in contact. But it has recently been shown that solids also mix, though very much more slowly.

2. If, for instance, a cube of lead is placed upon one of gold, the surfaces of contact being very smooth and true, and be left without any pressure but their own weight, and at ordinary temperatures, for about a month, a minute quantity of gold will be found to have permeated through the lead, and can be detected in any part of it. Metals may thus be said to flow into each other.

3. In order to produce chemical changes in bodies, it is usually necessary that one at least be a liquid or be in a state of solution, and the combinations that occur lead to the production of bodies having quite different properties from either of their components.

4. Similar results occur when metals are mixed together, forming alloys. Thus a mixture in certain

proportions of lead, tin, bismuth, and cadmium produces an alloy which melts in boiling water, while the component metals only melt at double that temperature or more. Again, the strength of gold is doubled by the addition of one five-hundredth part of the rare metal zirconium, indicating that the alloy must have a new arrangement of the molecules.

5. But the interesting point is, that alloys can be produced without melting the metals, for mere pressure often produces an alloy at the surfaces of contact; while in other cases, if fine filings of the component metals are thoroughly mixed together and then subjected to continued pressure, true alloys are produced.

6. Another interesting fact is that metals, and probably all solids, evaporate at ordinary temperatures. It has long been known that ice evaporates very rapidly, and now it is found that metals do the same, and the evaporation can be detected at temperatures far below their melting-points.

7. All these curious phenomena give us new ideas as to the constitution of matter, and lead us to the conclusion that the extreme mobility of the molecules of gases has its analogue in liquids, and even in solids.

8. The flow of metals, their diffusion into other metals, and their evaporation, lead to the conclusion that a proportion of their molecules must possess considerable mobility; and, when these reach the surface, they are enabled to escape, either into other bodies in contact with them or into the atmosphere. This proportion of rapidly moving molecules gives to solids some of the characteristics of liquids and of gases.

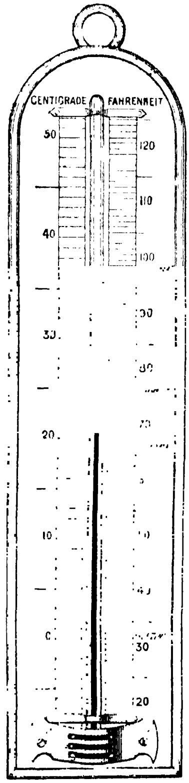
9. Before leaving this part of our subject, we must refer to a most interesting and suggestive discovery which throws still further light on the constitution of matter, and on the forces which give to matter

many of the properties without which neither vegetable nor animal life would be possible.

10. It has been found that all gases expand or contract equal amounts for every degree of heat, the amount being $\frac{1}{273}$ of their volume for each degree centigrade. If, therefore, beginning at the freezing-point, a gas could be cooled continuously down to -273 C. or -461 Fahr., it would not only be reduced to a solid, but would cease to have the power of further contraction. Hence this point is termed the absolute zero of temperature. Lord Kelvin has arrived at the same result by quite different means.

11. With the total absence of heat, it is believed that all chemical action would cease, so that the universe would consist wholly of solid and chemically inert matter. Heat, therefore, seems to be the source of all change in matter and the essential condition of all life, while the other vibrations of the ether, which we know as light and electricity, may be equally essential.

12. It seems probable, therefore, that ether is the active, matter the passive, agent in the constitution of the universe; and the recognition of the existence of the ether, together with the considerable amount of knowledge we have acquired of its modes of action, must be held to constitute one of the most important intellectual triumphs of the Nineteenth Century.



74. CENTIGRADE AND FAHRENHEIT THERMOMETERS COMPARED

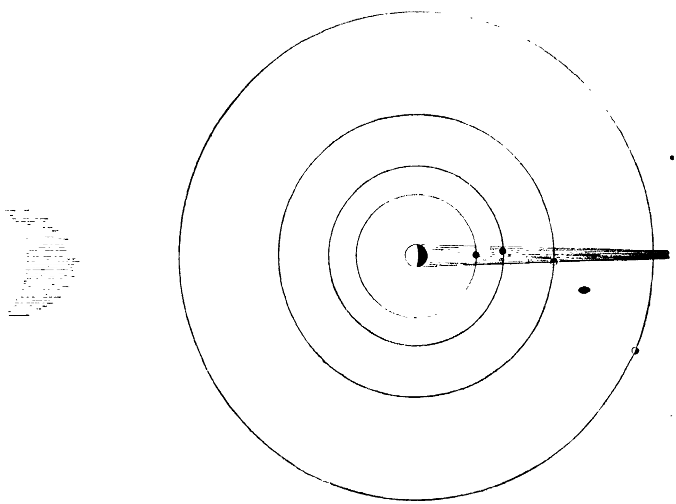
LESSON 26

(iv.) THE SPEED OF LIGHT

"Yes, thou shalt mark, with magic art profound,
The speed of light, the circling march of sound."
—CAMPBELL.

1. Among the very numerous discoveries depending upon physical principles or on the application of physical laws, a few of the more generally interesting may be here noticed.

2. The velocity of light, as is well known, was first

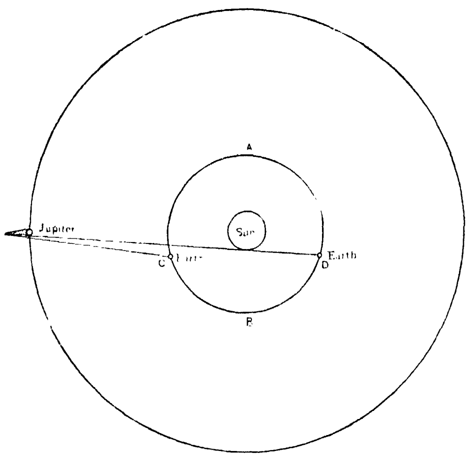


75. ECLIPSE OF JUPITER'S SATELLITES

determined in 1676 by the astronomer Roemer, through the observation of irregularities in the time of the eclipses of Jupiter's satellites, which were found to occur earlier or later than the calculated times, accord-

ing as we were near to or far from the planet. This is shown by the diagrams here given.

3. The first shows the planet Jupiter with the cone of shadow cast by it in space in a direction opposite to the sun. When one of the satellites enters this shadow, it becomes invisible at the same instant of time to observers in any direction or, theoretically, at any distance. The time of revolution of each of the



76. THE ORBITS OF THE EARTH AND OF JUPITER

satellites being very accurately known by centuries of careful observation, the occurrence of each eclipse can be predicted to a second, and is given in all astronomical almanacks.

4. Now referring to the second diagram, which shows the orbits of the earth and Jupiter on a very small scale, we see that these eclipses may be observed from the earth when it is almost at its nearest and also at its farthest distance from the planet, a difference of about

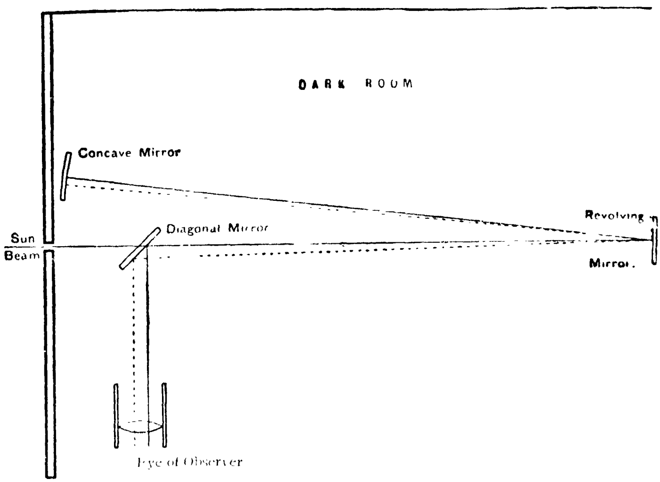
180 millions of miles. It was found, however, that when the earth was nearest, at C, the eclipses happened about eight minutes earlier, and when at D eight minutes later than the calculated time, while in the positions A and B the observations agreed with calculation. It was thus found that it required eight minutes for light to travel from the sun to the earth, a distance of a little more than ninety millions of miles; so that light travels about 196,000 miles in a single second of time.

5. It would seem at first sight impossible to measure the time taken by light in travelling a mile, yet means have been discovered to do this, and even to measure the time taken for light to traverse a few feet from one side of a room to the other. Yet more, this method of measuring the velocity of light has, by successive refinements, become so accurate that it is now considered to be the most satisfactory method of determining the mean distance of the sun from the earth, a distance which serves as the unit of measurement for the solar system and the whole stellar universe. A brief account of how this is effected will now be given.

6. Fizeau, a French physicist, made the first attempt at measuring the velocity of light in 1849; and later in 1862, in conjunction with Foucault, a more accurate determination was made by means of an apparatus of which the main features are given in the accompanying diagram.

7. A ray of sunlight is made to enter a darkened room by a narrow slit, and falls on a mirror at the farther side of the room, which can be made to revolve with great rapidity. From this it is reflected to a concave mirror having its centre of curvature at the revolving mirror.

8. The diagonal mirror is transparent glass, through which the ray passes on its way to the revolving mirror, but, on coming back, a portion of the light is reflected at right angles to the eye of the observer. This involves much loss of light, and in more recent experiments the revolving mirror is slightly tilted, so that the returning ray passes beneath the outgoing



77. DIAGRAM ILLUSTRATING MIRROR EXPERIMENT FOR ASCERTAINING VELOCITY OF LIGHT

ray, and is then reflected by a mirror or by a total-reflexion prism to the eye of the observer.

9. Now let us suppose the revolving mirror to be at rest. The various mirrors are first accurately adjusted, so that the narrow slit of light (or a fine wire in its centre) is so reflected by the three mirrors that it can be seen in the observing eye-piece, and its position on a fine micrometer exactly noted.

10. If now the mirror is slowly revolved, the line of light will appear and disappear at each revolution;

but if it is made to revolve more than thirty times a second, the line of light will be seen motionless, on the same principle that a rapidly moving luminous object is seen as an illuminated riband. But if light requires any time, however minute, to travel from the revolving to the concave mirror and back again, the mirror will during that time have turned a little on its axis, and the returning ray of light will be reflected to a slightly different point on the diagonal mirror and on the micrometer scale of the eye-piece.

11. In Foucault's experiment, the distance between the concave and revolving mirrors was only thirteen and a half feet, and he had to make the mirror revolve six hundred times in a second before the returning ray was shifted rather less than one-hundredth of an inch. By increasing the speed to eight hundred revolutions the distance was increased to about twelve-thousands of an inch, which, under a powerful magnifier, could be measured with great precision.

12. Having measured, with great accuracy, the distance between the mirrors, and knowing the exact number of revolutions a second of the mirror, which was shown by a simple clockwork connected with it, the velocity of light was deduced as being 185,157 miles per second.

13. It is evident that there are here several sources of error. The short distance traversed by the light renders it necessary for the revolving mirror to turn with extreme rapidity, while the observed displacement of the ray is very small. Minute errors in the various measurements will therefore be enormously multiplied in the result.

14. To obviate these difficulties, the concave mirror has been placed much farther away; and in the most recent and most accurate experiments by Professor

Newcomb at Washington, the distance between the revolving and the concave mirrors was about two and a half miles, and the mirror revolved two hundred and thirty times a second. This gave such a large displacement of the returning ray that it could be measured with extreme accuracy, and the average of numerous trials gave the velocity of light as 186,327 miles per second.

15. It thus appears that Foucault's measurement in a small room was only in error about $\frac{1}{180}$, or a little more than a half of one per cent., a wonderful testimony to his skill as an experimenter under such unfavourable conditions. Professor Newcomb believes that his determination is correct within $\frac{1}{10000}$, but he thinks that by placing the mirrors twenty or thirty miles apart in the clear atmosphere of the Rocky Mountains, a still greater approach to perfect accuracy could be obtained.[1]

LESSON 27

(v.) THE EARTH'S ROTATION

"But the sunshine aye shall light the sky,
As round and round we run."
—CHARLES MACKAY.

1. The same M. Leon Foucault, who made those beautiful experiments on the measurement of the velocity of light, has also discovered a method by which the rotation of the earth on its axis can be experimentally demonstrated.

2. When a heavy body is in free motion in any direction, it requires force to change the direction; and if no such force is applied, it will continue its

[1] For a more detailed account of Professor Newcomb's experiments, see *Nature*, vol. xxxiv. p. 170.

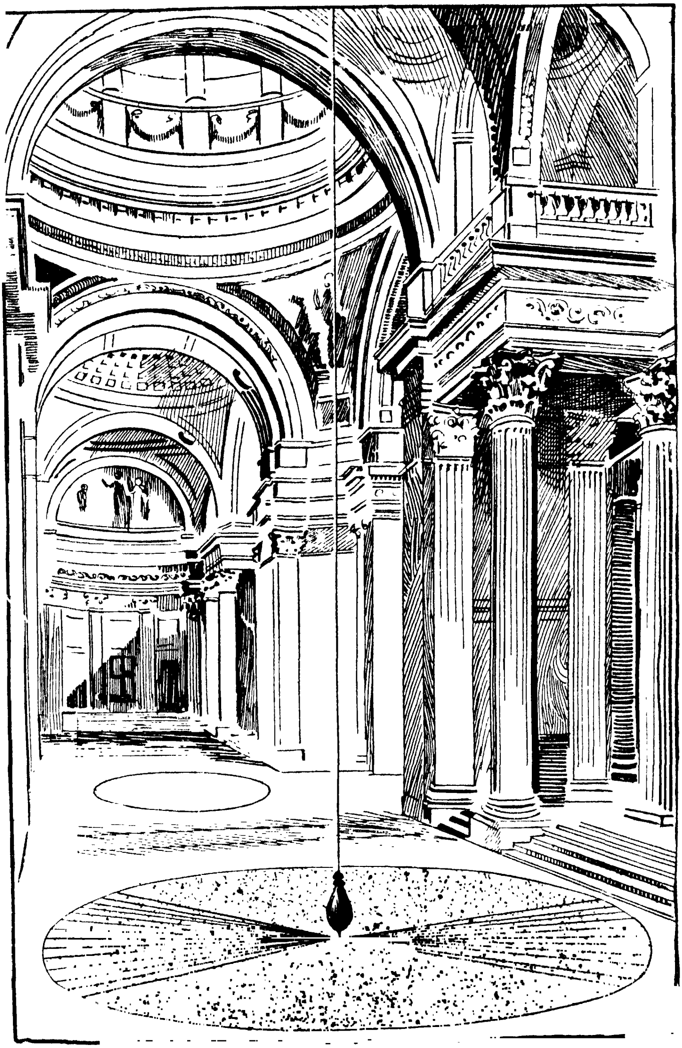
motion in the same straight line or in the same plane.

3. If a heavy pendulum is suspended from the axis of a horizontal wheel by a very long thin wire, and if, when swinging in a fixed line across the room, the wheel is slowly turned, either the wire will twist a little or the ball forming the weight of the pendulum will revolve, or, more probably, both these results will happen, but the plane in which the weight swings will not be altered. On the same principle, any pendulum freely swinging near the North Pole will not change the direction of its swing, although its point of support revolves in twenty-four hours with the earth's surface to which it is attached.

4. On trying the experiment with a heavy weight suspended from the dome of the Panthéon in Paris, and carefully set swinging, the plane of oscillation of the weight was found apparently to change at a uniform rate, and always in the same direction, which was opposite to that of the earth's rotation; proving that the surface of the earth moved round while the plane of oscillation remained fixed in space.

5. This experiment can be tried in any place free from currents of air, such as a cellar. It only requires a heavy weight, say of 28 lbs., to be suspended by a string just strong enough to bear it. The weight must be drawn three or four feet away from the vertical line and fastened by a thread, so as to be set swinging by burning the thread without giving it any lateral motion. In an hour the line of swing will be found to have changed considerably, and in a direction opposite to that of the earth's rotation.

6. At the North Pole, a circle drawn on the surface turns completely round in twenty-four hours, so that a pendulum swung there with a circle beneath it, divided



78. FOUCAULT'S EXPERIMENT TO SHOW THE EARTH'S ROTATION

like a twenty-four hour clock-dial, would appear to revolve, and would tell the time.

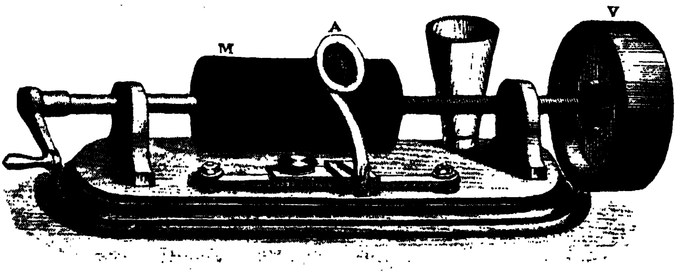
7. At the Equator, however, a circle on the surface of the earth does not itself rotate on its centre as at the Pole, but is merely carried round the earth, with the north and south points of the circumference preserving the same direction in space. Therefore, at the Equator, a pendulum should show no motion of rotation.

8. At all intervening points it will appear to rotate, but slower and slower as we recede from the Pole; and mathematical calculation shows that, while at the Pole it apparently moves through an angle of 15° in an hour, at London it would move a little less than 12°, at Paris $11\frac{1}{2}$°, at New York $9\frac{3}{4}$°, and at Ceylon somewhat less than 2°, an hour.

9. Experiments have been tried at each of these places, and the rate of apparent rotation of the pendulum has been found to agree very closely with the calculated amount, thus giving a complete proof that the apparent rotation is really due to the rotation of the earth on its axis. This mode of rendering the earth's rotation visible in such a simple and convincing manner is a discovery of considerable interest, even among the many wonderful discoveries of the past century.

10. A pendulum of this kind can be seen in the Museum at South Kensington, but any one can try it for himself, who has access to a cellar or any closed room in which such a pendulum can be set swinging; and if carried out as suggested in par. 5 of this lesson it is sure to succeed, and will be much more interesting and convincing than any account of the experiments made by others.

LESSON 28



79. THE PHONOGRAPH

) SOUND RECORDERS

;chless Age! that even the passing tone
och-making speech, or lover's sigh,
rdest for the wonder of all time!"

—F. T. Mott.

1. One more of these minor applications of scientific principles, leading to very startling results, must be briefly described.

2. All sounds, including the infinitely varied modulations of the human voice, have long been known to be due to successive air-waves set up by various vibrating substances; but it would seem impossible by any mechanical means to reproduce these complex vibrations so exactly as to cause the words of the original speaker to be again heard quite intelligibly, and with all their tones and modulations, at any distant time or place. Yet this has been done by means of the instrument called the phonograph, one of the many ingenious inventions of the American, Edison.

3. In the telephone this is effected instantaneously,

through the medium of an electric current, which reproduces the vibrations set up by the voice of the speaker in a delicate elastic diaphragm by means of

80. RECORDING A DUET BY THE PHONOGRAPH

another diaphragm at the end of the conducting wire, perhaps hundreds of miles away, as already explained in Lesson 10.

4. In the phonograph, the whole operation is mechanical. A diaphragm is set vibrating by the voice as in the telephone, but instead of being reproduced at a distance by means of an electric current, it registers itself permanently on a cylinder of very hard wax, as an indented spiral line. This is effected by means of a fine steel point, like a graving tool, connected by a delicate lever with the centre of the diaphragm.

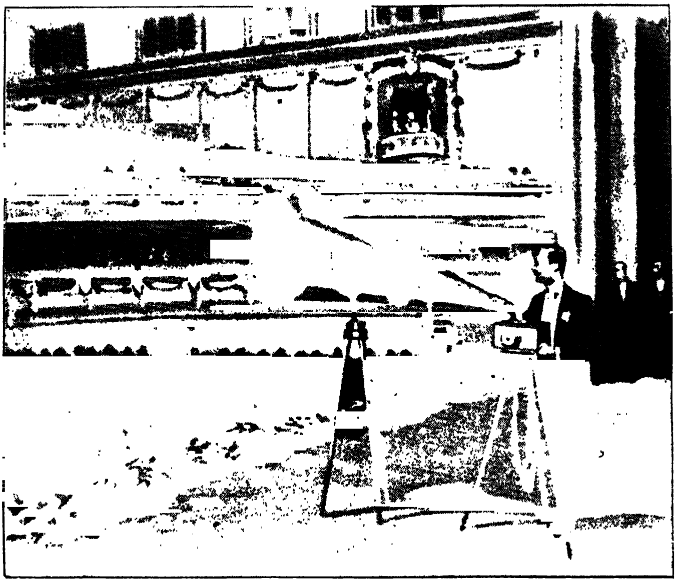
5. The wax cylinder turns and travels onward with a screw motion at a perfectly uniform rate, which can be delicately adjusted, so that the steel point, if stationary, will cut in it a very fine spiral groove, uniform in depth from end to end, the turns of the groove being very close to each other. But when the diaphragm is set vibrating by the voice of the speaker, the steel point moves rapidly up and down, and the resulting groove continually varies in depth, forming a complex series of undulations.

6. If, now, the cylinder is shifted back, so that the steel point is exactly where it was at starting, and the cylinder is then made to revolve and move onward at exactly the same rate as before, the up-and-down motions of the style, due to the irregular depth of the groove, produce the very same series of vibrations in the diaphragm as those which cut the groove; and these vibrations reproduce the voice with marvellous fidelity, so that the most complex and rapid speech, or the most exquisite singing, can be heard quite intelligibly, and with all their modulations and expressiveness, though not in exactly the same tone of voice.

7. The cylinders thus produced can be preserved for years, can be carried to any part of the world, and by means of a duplicate of the original instrument will

there reproduce the words and many of the vocal peculiarities of the speaker.

8. Phonographs are now largely manufactured, and are used for a variety of purposes. They serve for the rapid dictation of correspondence, which can be reproduced and copied by a clerk later on; to take down discussions verbatim, with a perfection that no short-



81. A PHONOGRAPHIC CONCERT

hand writer can rival; the singing or the elocution of celebrated performers is repeated for the gratification of friends or to amuse private parties; actors, musicians, and clergymen use the instrument as a means of improving their style; and even the languages, songs, and folk-lore of dying-out tribes are being preserved on these wonderful cylinders.

9. Probably there is no instrument in the world which so impresses the observer with the apparent inadequacy of the means to bring about so marvellous a result. At the same time, it renders more mysterious than ever the properties and possibilities of air-waves, and the extreme delicacy of the ear and auditory nerves, which enable us instantaneously to interpret any one set of these vibrations, amidst the many other sets of air-waves arising from various sources which must be continually crossing and intermingling in apparently inextricable confusion. The phonograph, whether as illustrating the ingenuity of man or the marvellous perfection of our organism, will certainly take high rank among the new inventions of the Nineteenth Century.

LESSON 29

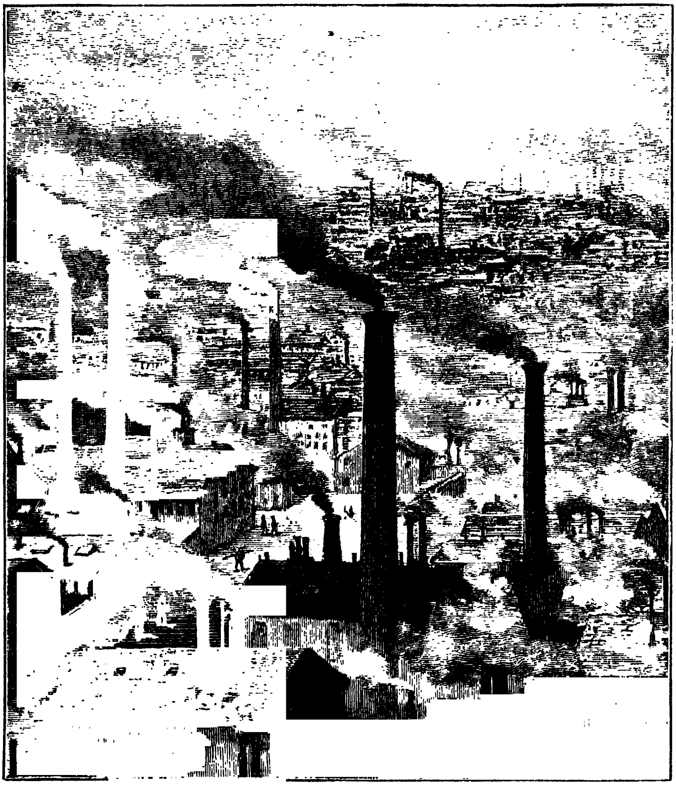
(i.) DUST

> "When the lamp is shattered,
> The light in the dust lies dead;
> When the cloud is scattered,
> The rainbow's glory is shed."
>
> —SHELLEY.

1. The majority of persons, if asked what were the uses of dust, would reply that they did not know it had any, but they were sure it was a great nuisance. It is true that dust, in our towns and in our houses, is often not only a nuisance but a serious source of disease; while in many countries it produces ophthalmia, often resulting in total blindness.

2. Dust, however, as it is usually perceived by us, is, like dirt, only matter in the wrong place, and whatever injurious or disagreeable effects it produces are largely due to our own dealings with nature.

3. So soon as we dispense with horse-power and adopt purely mechanical means of traction and conveyance, we can almost wholly abolish disease-bearing dust from our streets, and ultimately from all our



82. A DUST-PRODUCING TOWN

highways; while another kind of dust, that caused by the imperfect combustion of coal, may be got rid of with equal facility so soon as we consider pure air, sunlight, and natural beauty to be of more importance

83. DUST-PRODUCING HORSE TRAFFIC (AT THE BANK, LONDON)

to the population as a whole than are the prejudices or the vested interests of those who produce the smoke.

4. But though we can thus minimise the dangers and the inconveniences arising from the grosser forms of dust, we cannot wholly abolish it; and it is, indeed, fortunate we cannot do so, since it has now been discovered that it is to the presence of dust we owe much of the beauty, and perhaps even the very habitability, of the earth we live upon. Few of the fairy tales of science are more marvellous than these recent discoveries as to the varied effects and important uses of dust in the economy of nature.

5. The question why the sky and the deep ocean are both blue did not much concern the earlier physicists. It was thought to be the natural colour of pure air and water, so pale as not to be visible when small quantities were seen, and only exhibiting its true tint when we looked through great depths of atmosphere or of oceanic water.

6. But this theory did not explain the familiar facts of the gorgeous tints seen at sunset and sunrise, not only in the atmosphere and on the clouds near the horizon, but also in equally resplendent hues when the invisible sun shines upon alpine peaks and snowfields. A true theory should explain all these colours, which comprise almost every tint of the rainbow.

7. The explanation was found through experiments on the visibility or non-visibility of air, which were made by the late Professor Tyndall about the year 1868. Every one has seen the floating dust in a sunbeam when sunshine enters a partially darkened room; but it is not generally known that if there was absolutely no dust in the air the path of the sunbeam would be totally black and invisible, while if only very little dust was present in very minute particles, the air would be as blue as a summer sky.

8. This was proved by passing a ray of electric light lengthways through a long glass cylinder filled with air of varying degrees of purity as regards dust. In the air of an ordinary room, however clear and well ventilated, the interior of the cylinder appears brilliantly illuminated.

9. But if the cylinder is exhausted and then filled with air which has passed slowly through a fine gauze of intensely heated platinum wire, so as to burn up all the floating dust-particles, which are mainly organic, the light will pass through the cylinder without illuminating the interior, which, viewed laterally, will appear as if filled with a dense black cloud.

10. If, now, more air is passed into the cylinder through the heated gauze, but so rapidly that the dust-particles are not wholly consumed, a slight blue haze will begin to appear, which will gradually become a pure blue, equal to that of a summer sky. If more and more dust-particles are allowed to enter, the blue becomes paler, and gradually changes to the colourless illumination of the ordinary air.

11. The explanation of these phenomena is, that the number of dust-particles in ordinary air is so great and their size is comparatively so large, that they reflect abundance of light of all wave-lengths, and thus cause the interior of the vessel containing them to appear illuminated with white light. The air which has passed slowly over white-hot platinum has had the dust-particles destroyed, thus showing that they were almost wholly of organic origin, which is also indicated by their extreme lightness, causing them to float permanently in the atmosphere.

12. The dust being thus got rid of, and pure air being entirely transparent, there is nothing in the cylinder to reflect the light which is sent through its

centre in a beam of parallel rays, so that none of it strikes against the sides; hence the inside of the cylinder appears absolutely dark. But when all the larger dust-particles are wholly or partially burnt, so that only the very smallest fragments remain, a blue light appears, because these are so minute as to reflect chiefly the more refrangible rays, which are of shorter wave-length—those at the blue end of the spectrum, which are thus scattered in all directions, while the red and yellow rays pass straight on as before.

LESSON 30

(ii.) DUST A SOURCE OF BEAUTY

"Like a fountain troubled,
Muddy, ill-seeming, thick, bereft of beauty."
—SHAKESPEARE.

1. We have seen that the air near the earth's surface is full of rather coarse particles, which reflect all the rays, and which, therefore, produce no special colour; but higher up the particles necessarily become smaller and smaller, since the comparatively rare atmosphere will only support the very smallest and lightest.

2. These exist throughout a great thickness of air, perhaps from one mile to ten miles high, or even more, and blue or violet rays being reflected from the innumerable particles in this great mass of air, which is nearly uniform in all parts of the world as regards the presence of minute dust-particles, produces the constant and nearly uniform tint we call sky-blue. A certain amount of white or yellow light is no doubt reflected from the coarser dust in the lower atmosphere, and slightly dilutes the blue and renders it not quite so deep and pure as it otherwise would be.

3. This is shown by the increasing depth of the sky-colour when seen from the tops of lofty mountains, while from the still greater heights attained in balloons the sky appears of a blue-black colour, the blue reflected from the comparatively small amount of dust-particles being seen against the intense black of stellar space.

4. It is for the same reason that the "Italian skies" are of so rich a blue, because the Mediterranean Sea on one side and the snowy Alps on the other, do not furnish so large a quantity of atmospheric dust in the lower strata of air as in less favourably situated countries, thus leaving the blue reflected by the more uniformly distributed fine dust of the higher strata undiluted. But these Mediterranean skies are surpassed by those of the Central Pacific Ocean, where, owing to the small area of land, the lower atmosphere is more free from coarse dust than any other part of the world.

5. If we look at the sky on a perfectly fine summer's day, we shall find that the blue colour is the most pure and intense overhead and when looking high up in a direction opposite to the sun. Near the horizon it is always less bright, while in the region immediately round the sun it is more or less yellow.

6. The reason of this is, that near the horizon we look through a very great thickness of the lower atmosphere, which is full of the larger dust-particles reflecting white light, and this dilutes the pure blue of the higher atmosphere seen beyond. And in the vicinity of the sun a good deal of the blue light is reflected back into space by the finer dust, thus giving a yellowish tinge to that which reaches us reflected chiefly from the coarse dust of the lower atmosphere.

7. At sunset and sunrise, however, this last effect is greatly intensified, owing to the great thickness of the strata of air through which the light reaches us.

The enormous amount of this dust is well shown by the fact that then only can we look full at the

84. A SUNRISE SKY

sun, even when the whole sky is free from clouds and there is no apparent mist.

8. But the sun's rays then reach us after having passed, first, through an enormous thickness of the higher strata of the air, the very fine dust of which reflects most of the blue rays away from us, leaving the complementary yellow light to pass on. Then the somewhat coarser dust reflects the green rays, leaving a more orange-coloured light to pass on; and finally some of the yellow is reflected, leaving almost pure red.

9. Owing, however, to the constant presence of air currents, arranging both the dust and vapour in strata of varying extent and density, and of high or low clouds, which both absorb and reflect the light in varying degrees, we see produced all those wondrous combinations of tints and those gorgeous ever-changing colours which are a constant source of admiration and delight to all who have the advantage of an uninterrupted view to the west, and who are accustomed to watch for these not unfrequent exhibitions of nature's kaleidoscopic colour-painting. With every change in the altitude of the sun the display changes its character; and most of all when it has sunk below the horizon, and owing to the more favourable angles, a larger quantity of the coloured light is reflected towards us.

10. Especially when there is a certain amount of cloud is this the case. These, so long as the sun was above the horizon, intercepted much of the light and colour; but, when the great luminary has passed away from our direct vision, his light shines more directly on the under sides of all the clouds and air strata of different densities; a new and more brilliant light flushes the western sky, and a display of gorgeous ever-changing tints occurs, which are at once the delight of the beholder and the despair of the artist. And all this unsurpassable glory we owe to—dust!

LESSON 31

(iii.) VOLCANIC AND OCEANIC DUST

"Blue, darkly, deeply, beautifully blue."
—SOUTHEY.

1. A remarkable confirmation of this theory was given during the two or three years after the great eruption of Krakatoa, near Java, in 1883. The sound of the explosions was heard at Ceylon, Manilla, and West Australia, while the volcanic matter was shot up from the crater many miles high, and the heavier portion of it fell upon the sea for several hundred miles around to the depth of two or three feet, and was found to be mainly composed of very thin flakes of volcanic glass.

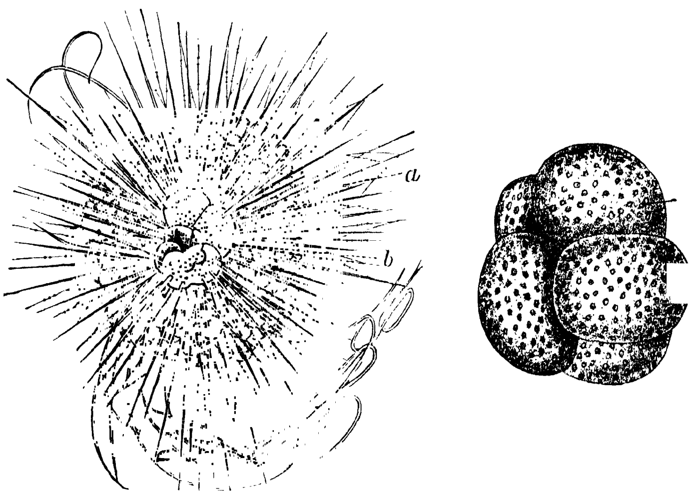
2. Much of this was of course ground to impalpable dust by the violence of the discharge, and was carried up to a height of many miles. Here it was caught by the return current of air continually flowing northwards and southwards above the equatorial zone; and as these currents reach the temperate zone, where the surface rotation of the earth is less rapid, they continually flow eastward, and the fine dust was thus carried at a great altitude completely round the earth.

3. Its effects were traced some months after the eruption in the appearance of brilliant sunset-glows of an exceptional character, often flushing with crimson the whole western half of the visible sky, and sometimes extending across the zenith and over a portion of the eastern half. These glows continued in diminishing splendour for about three years; they were seen all over the temperate zone, and it was calculated that, before they finally disappeared, some of this fine dust must have travelled three times round the globe.

85. A VOLCANIC ERUPTION AT THE ISLAND OF KRAKATOA IN THE STRAITS OF SUNDA, MIDWAY BETWEEN JAVA AND SUMATRA

(From a Photograph taken shortly after the Eruption)

4. The same principle was at first thought to explain the exquisite blue colour of the deep seas and oceans and of many lakes and springs. Absolutely pure water, like pure air, was held to be colourless, but it is now known to have really a blue tint of its own. It has been proved, however, that the apparent colour of the deep ocean is largely due to reflection from solid particles suspended in the water, which greatly intensify the colour. Where these particles are very few, there is not enough light reflected through a great depth of water to show its colour, which is thus rendered dusky by being seen against the black depths of the ocean, to which light never penetrates.



86. EXAMPLES OF ORGANISMS, THE SHELLS OF WHICH CONSTITUTE DEEP-SEA OOZE. THEY ARE, ROUGHLY, THE SIZE OF GRAINS OF SEA-SAND

5. The oceanic dust is derived from many sources. Minute organisms are constantly dying near the surface, and their skeletons, or fragments of them, fall

slowly to the bottom. The mud brought down by rivers, though it cannot be traced on the ocean floor more than about 150 miles from land, yet no doubt furnishes many particles of organic matter which are carried by surface currents to enormous distances, and are ultimately dissolved before they reach the bottom.

6. A more important source of finely divided matter is to be found in volcanic dust, which, as in the case of Krakatoa, may remain for years in the atmosphere, but which must ultimately fall upon the surface of the earth and ocean. This can be traced in all the deep-sea oozes.

7. Finally there is meteoric dust, which is continually falling to the surface of the earth in minute quantities and can be detected in the oozes of the deepest oceans.

8. The blue of the ocean varies in different parts from a very pure blue somewhat lighter than that of the sky, as seen about the northern tropic in the Atlantic, to a deep indigo tint, as seen in the north temperate portions of the same ocean; due, probably, to differences in the nature, quantity, and distribution of the solid matter, which, by reflecting the blue tint of the water, intensifies the colour. The Mediterranean and the deeper Swiss lakes are also blue of various tints, due also to the presence of suspended matter, which Professor Tyndall thought might be so fine that it would require ages of quiet subsidence to reach the bottom.

9. All the evidence goes to show, therefore, that the exquisite blue tints of sky and ocean, as well as all the sunset hues of sky and cloud, of mountain peak and alpine snows, are due, either wholly or partially, to that very dust which, in its coarser forms, we find so annoying and often so dangerous.

LESSON 32

(iv.) DUST ESSENTIAL TO LIFE

"How beautiful is the rain!
After the dust and heat,
In the broad and fiery street,
In the narrow lane,
How beautiful is the rain!"
—LONGFELLOW.

1. But if this production of colour and beauty were the only useful function of dust, some persons might be disposed to dispense with it, in order to escape its less agreeable effects. It has, however, been recently discovered that dust has another part to play in nature, a part so important that it is doubtful whether we could even live without it. To the presence of dust in the higher atmosphere, we owe the formation of mists, clouds, and gentle beneficial rains, instead of waterspouts and destructive torrents.

2. It is barely twenty years ago since the discovery was made, first in France by Coulier and Mascart, but more thoroughly worked out by Mr. John Aitken in 1880. He found that if a jet of steam is admitted into two large glass receivers, one filled with ordinary air, the other with air which has been filtered through cotton-wool so as to keep back all particles of solid matter, the first will be instantly filled with condensed vapour in the usual cloudy form, while the other vessel will remain quite transparent.

3. Another experiment was made more nearly reproducing what occurs in nature. Some water was placed in the two vessels prepared as before. When the water had evaporated sufficiently to saturate the air, the vessels were slightly cooled, when a dense

cloud was at once formed in the one, while the other remained quite clear.

4. These experiments, and many others, showed that the mere cooling of vapour in air will not condense it into mist, clouds, or rain, unless *particles of solid matter* are present to form *nuclei* upon which condensation can begin. The density of the cloud is proportionate to the number of the particles; hence the fact that the steam issuing from the safety-valve or the chimney of a locomotive forms a dense white cloud, shows that the air is really full of dust-particles, most of which are microscopic, but none the less serving as centres of condensation for the vapour.

5. It follows, therefore, that if there were no dust in the air, escaping steam would remain invisible; there would be no clouds in the sky; and the vapour in the atmosphere, constantly accumulating through evaporation from seas and oceans and from the earth's surface, would have to find some other means of returning to its source.

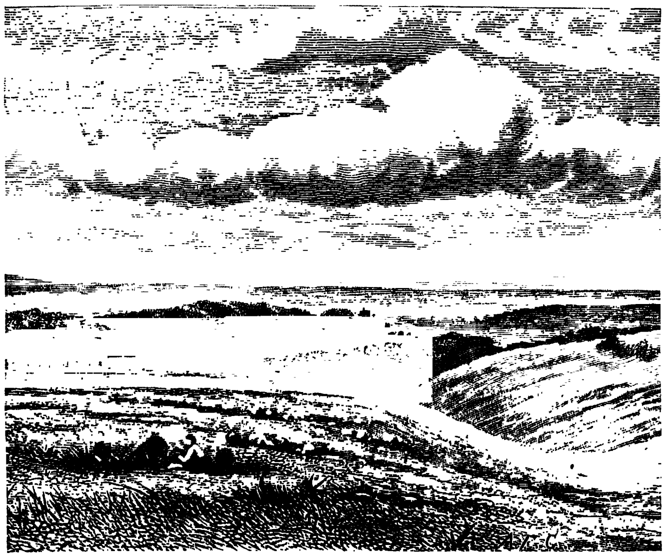
6. One of these modes would be the deposition of dew, which is itself an illustration of the principle that vapour requires solid or liquid surfaces to condense upon, as shown by the fact that dew forms more readily and more abundantly on grass, on account of the numerous centres of condensation it affords.

7. Dew, however, is formed only on clear cold nights after warm or moist days. The air near the surface is warm and contains much vapour, though below the point of saturation; but the innumerable points and extensive surfaces of grass radiate heat quickly, and becoming cool, lower the temperature of the adjacent air, which then reaches saturation-point and condenses the contained vapour on the grass.

8. If, then, the atmosphere at the earth's surface

became super-saturated with aqueous vapour, dew would be continuously deposited, especially on every form of vegetation, the result being that everything, including our clothing, would be constantly dripping wet.

9. If there were absolutely no particles of solid matter in the upper atmosphere, all the moisture



87. A COMMON CLOUD-FORM
(The Heap-Cloud or Cumulus)

would be returned to the earth in the form of dense mists near the ground, and frequent and copious dews, which in forests would form torrents of rain by the rapid condensation on the leaves.

10. But if we suppose that solid particles were occasionally carried high up through violent winds or tornadoes, then on those occasions the super-saturated

air would condense rapidly upon them, and while falling the drops would gather almost all the moisture in the atmosphere in that locality, resulting in masses or sheets of water, which would be so ruinously destructive by the mere weight and impetus of their fall that it is doubtful whether they would not render the earth almost wholly uninhabitable.

11. The chief mode of discharging the atmospheric vapour in the absence of dust would, however, be by contact with the higher slopes of all mountain ranges. Atmospheric vapour, being lighter than air, would accumulate in enormous quantities in the higher strata of the atmosphere, which would be always super-saturated and ready to condense upon any solid or liquid surfaces.

12. But the quantity of land comprised in the upper half of all the mountains of the world is a very small fraction of the total surface of the globe, and this would lead to very disastrous results. The air in contact with the higher mountain slopes would rapidly discharge its water, which would run down the mountain sides in torrents.

13. This condensation on every side of the mountains would leave a partial vacuum, which would set up currents from every direction to restore the equilibrium, thus bringing in more super-saturated air to suffer condensation and add its supply of water, again increasing the in-draught of more air. The result would be, that winds would be constantly blowing towards every mountain range from all directions, keeping up the condensation and discharging, day and night and from one year's end to another, an amount of water equal to that which falls during the heaviest tropical rains.

14. The whole of the rain that now falls over the

entire surface of the earth and ocean, with the exception of a few desert areas, would then fall only on rather high mountains or steep isolated hills, tearing down their sides in huge torrents, cutting deep ravines, and rendering all growth of vegetation impossible. The mountains would therefore be so devastated as to be uninhabitable, and would be equally incapable of supporting either vegetable or animal life.

15. But this constant condensation on the mountains would probably check the deposit on the lowlands in the form of dew, because the continual up-draught towards the higher slopes would withdraw almost the whole of the vapour as it rose from the oceans and other water-surfaces, and thus leave the lower strata over the plains almost or quite dry.

16. And if this were the case, there would be no vegetation, and therefore no animal life, on the plains and lowlands, which would thus be all arid deserts cut through by the great rivers formed by the meeting together of the innumerable torrents from the mountains.

17. Now, although it may not be possible to determine with perfect accuracy what would happen under the supposed condition of the atmosphere, it is certain that the total absence of dust would so fundamentally change the meteorology of our globe as, not improbably, to render it uninhabitable by man, and equally unsuitable for the larger portion of its existing animal and vegetable life. Even this, however, does not exhaust the effects of dust upon our possibilities of life and enjoyment; and in the next two lessons we shall see, not only other evils that would result from the total absence of dust, but also some which we probably suffer from our careless production of too much of it.

LESSON 33

OUR DEBT TO DUST (1)

"Go forth under the open sky, and list
To Nature's teachings."
—W. C. BRYANT.

WITH DUST—SOFT SHADOWS

1. Let us now briefly summarise what we owe to the universality of dust, and especially to that most finely divided portion of it which is constantly present in the atmosphere up to the height of many miles.

88. WITHOUT DUST—DARK SHADOWS

2. First of all it gives us the pure blue of the sky, one of the most exquisitely beautiful colours in nature. It gives us also the glories of the sunset and the sunrise, and all those brilliant hues seen in high mountain regions. Half the beauty of the world would vanish with the absence of dust. But, what is far more important than the colour of sky and beauty of sunset, dust gives us also diffused daylight or skylight, that most equable, and soothing, and useful of all illuminating agencies.

3. Without dust, the sky would appear absolutely black, and the stars would be visible even at noonday. The sky itself would, therefore, give us no light. We should have bright glaring sunlight or intensely dark shadows, with hardly any half-tones.

4. From this cause alone, the world would be so totally different from what it is, that all vegetable and animal life would probably have developed into very different forms, and even our own organisation would have been modified in order that we might enjoy life in a world of such harsh and violent contrasts.

5. In our houses we should have little light, except when the sun shone directly into them, and even then every spot out of its direct rays would be completely dark, except for light reflected from the walls. It would be necessary to have windows all round and the walls all white; and on the north side of every house a high white wall would have to be built to reflect the light and prevent that side from being in total darkness. Even then we should have to live in a perpetual glare, or shut out the sun altogether and use artificial light as being a far superior article.

6. Much more important would be the effects of a dust-free atmosphere in banishing clouds, or mist, or the "gentle rain of heaven," and in giving us in their place perpetual sunshine, desert lowlands, and mountains devastated by unceasing floods and raging torrents, so as, apparently, to render all life on the earth impossible.

7. There are a few other phenomena, apparently due to the same general causes, which may here be referred to. Every one must have noticed the difference in the atmospheric effects and general character of the light in spring and autumn, at times when the days are of the same length, and consequently

when the sun has the same altitude at corresponding hours.

8. In spring we have a bluer sky and greater transparency of the atmosphere; in autumn, even on very fine days, there is always a kind of yellowish haze, resulting in a want of clearness in the air and purity

89. A CLEAR SPRING MORNING

of colour in the sky. These phenomena are quite intelligible when we consider that during winter less dust is formed, and more is brought down to the earth by rain and snow, resulting in the transparent atmosphere of spring, while exactly opposite conditions during summer bring about the mellow autumnal light.

9. Again, the well-known beneficial effects of rain

on vegetation, as compared with any amount of artificial watering, though, no doubt, largely due to the minute quantity of ammonia which the rain brings down with it from the air, must yet be partly derived from the organic or mineral particles which serve as the nuclei of every raindrop, and which, being so minute, are more readily dissolved in the soil and appropriated as nourishment by the roots of plants.

LESSON 34

OUR DEBT TO DUST (2)

"I am the daughter of Earth and Water,
And the nursling of the Sky."

—*The Cloud.* SHELLEY.

1. It will be observed that all these beneficial effects of dust are due to its presence in such quantities as are produced by natural causes, since both gentle showers as well as ample rains and deep blue skies, are present throughout the vast equatorial forest districts, where dust-forming agencies seem to be at a minimum.

2. But in all densely populated countries, there is an enormous artificial production of dust—from our ploughed fields, from our roads and streets, where dust is continually formed by the iron-shod hoofs of innumerable horses, but chiefly from our enormous combustion of fuel pouring into the air volumes of smoke charged with unconsumed particles of carbon.

3. This superabundance of dust, probably many times greater than that which would be produced under the more natural conditions which prevailed when our country was more thinly populated, must

almost certainly produce some effect on our climate; and the particular effect it seems calculated to produce is the increase of cloud and fog, but not necessarily any increase of rain.

4. Rain depends on the supply of aqueous vapour by evaporation; on temperature, which determines the dew-point; and on changes in barometric pressure, which determine the winds. There is probably always and everywhere enough atmospheric dust to serve as centres of condensation at considerable altitudes, and thus to initiate rainfall when the other conditions are favourable; but the presence of increased quantities of dust at the lower levels must lead to the formation of denser clouds, although the minute water-vesicles cannot descend as rain, because, as they pass down into warmer and dryer strata of air, they are again evaporated.

5. Now, there is much evidence to show that there has been a considerable increase in the amount of cloud, and consequent decrease in the amount of sunshine, in all parts of our country. It is an undoubted fact that throughout the Middle Ages England was a wine-producing country, and this implies more sunshine than we have now. Stow, the historian, states, that in the time of Richard the Second there were vineyards in Windsor Park, and the wine made from them was served at the king's table, showing that it was of good quality.

6. Sunshine has a double effect, in heating the surface soil and thus causing more rapid growth, besides its direct effect in ripening the fruit. This is well seen in Canada, where, notwithstanding a six months' winter of extreme severity, vines are grown as bushes in the open ground, and produce fruit equal to that of our ordinary greenhouses.

7. Some years back one of our gardening periodicals obtained from gardeners of forty or fifty years' experience, a body of facts clearly indicating a compara-

90. A CANADIAN FRUIT HARVEST

tively recent change of climate. It was stated that in many parts of the country, especially in the North,

fruits were formerly grown successfully and of good quality in gardens where they cannot be grown now; and this occurred in places sufficiently removed from manufacturing centres to be unaffected by any direct deleterious influence of smoke.

8. But an increase of cloud, and consequent diminution of sunshine, would produce just such a result; and this increase is almost certain to have occurred, owing to the enormously increased amount of dust thrown into the atmosphere as our country has become more densely populated, and especially owing to the vast increase of our smoke-producing manufactories.

9. It seems highly probable, therefore, that to increase the wealth of capitalist-manufacturers we are allowing the climate of our whole country to be greatly deteriorated in a way which diminishes both its productiveness and its beauty, thus injuriously affecting the enjoyment and the health of the whole population, since sunshine is itself an essential condition of healthy life. When this fact is thoroughly realised, we shall surely put a stop to such a reckless and wholly unnecessary production of injurious smoke and dust.

10. In conclusion, we find that the much-abused and all-pervading dust, which, when too freely produced, deteriorates our climate and brings us dirt, discomfort, and even disease, is, nevertheless, under natural conditions, an essential portion of the economy of nature.

11. It is to dust that we owe the brilliant blue of the summer sky, as well as the transparent greens or blues of our lakes, seas, and oceans. The same dust gives us mists and rains, and the beautiful phenomenon of the rainbow.

12. It gives us much of the beauty of natural

scenery as due to varying atmospheric effects of sky, and cloud, and sunset tints, and thus renders life more enjoyable; while, as an essential condition of diffused daylight, and of moderate rainfalls combined with a dry atmosphere, it appears to be absolutely necessary for our existence upon the earth, perhaps even for the very development of terrestrial, as opposed to aquatic life.

13. The overwhelming importance of the small things, and even of the despised things of our world, has never, perhaps, been so strikingly brought home to us as in these recent investigations into the wide-spread and far-reaching beneficial influences of atmospheric dust.

LESSON 35

ELEMENTS AND ATOMS (1)

[NOTE.—Lessons 35 and 36 had better be passed over unless the class has had some instruction in Practical Chemistry.]

"Force merges into force,
  The atom seeks its kind;
The elements are one,
  And each with all combined."

—F. T. PALGRAVE.

1. The science of modern chemistry has been created during the present century, but its phenomena and laws are so complex that it presents only a few of those great discoveries which are the starting-points for new developments, and which can at the same time be popularly described. The most important of all—that which constitutes the very foundation of chemistry as a science—is the law of chemical combination in multiple proportions, together with the atomic theory which serves to explain it.

2. The fact of chemical combination in definite proportions was suspected by some of the older chemists, but Dalton, in the early years of this century, was the first to establish it firmly as a general principle, and to explain it by means of a comparatively simple theory.

91. JOHN DALTON, F.R.S.

To illustrate by examples, it is found that the two gases nitrogen and oxygen combine to form a variety of compounds, such as nitrous oxide or "laughing gas," nitric oxide, and several others.

3. Nitrous oxide, or, in chemical language, nitrogen

monoxide, consists of 28 parts by weight of nitrogen to 16 of oxygen, and all the other compounds of the same gases consist of two, three, four, or five times as much oxygen to the same quantity of nitrogen. Water consists of 16 parts of oxygen to 2 of hydrogen, and there is another compound in which 32 parts of oxygen combine with the same weight of hydrogen, forming hydrogen-dioxide or oxygenated water.

4. This law applies to every chemical compound yet discovered, and as every element has a minimum proportionate weight which can combine with any other element, these are called the atomic or combining weights of the elements. As the weight of the hydrogen in all its combinations is much less than the weight of the element it combines with, this gas is taken as the unit of measurement of atomic weights.

5. Nitrogen is thus found to have an atomic weight of 14, oxygen 16, and chlorine 35. These are all gases; but many solids have much lower atomic weights, carbon being 12, and the rare metal beryllium only 9. Of other metals, that of aluminium is 27, copper 63, iron 56, silver 107, tin 117, and gold 196.

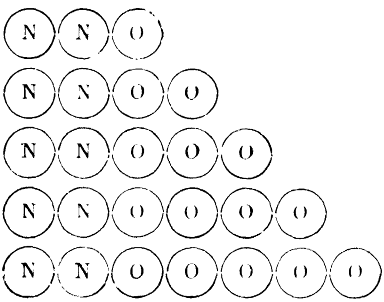
6. There is thus no constant relation between atomic weights and specific gravities. Tin is a little lighter than iron, but has nearly double its atomic weight; gold has a high atomic weight, but bismuth has a higher still, although only half its specific gravity.

7. These facts are elucidated, and to some extent explained, by the atomic theory of Dalton. He supposed each element to consist of atoms, an atom being the smallest portion that has the properties of the element, and the atom of each element has a different weight. Hence when one element combines with another, the proportions must be either those repre-

sented by the atomic weights, or some multiple of those weights, since the atoms are assumed to be indivisible.

8. This will be made clearer by another example. The atomic weights of nitrogen and oxygen are as 14 to 16, and these elements combine in five different proportions, as shown by the following figures, each circle representing an atom of the elements indicated by their initial letters:

Chemical Symbol



=Nitrogen monoxide N_2O

=Nitrogen dioxide N_2O_2

=Nitrogen trioxide N_2O_3

=Nitrogen tetroxide N_2O_4

=Nitrogen pentoxide N_2O_5

9. The atomic or combining weights of all the elements having been carefully determined by numerous experiments, a beautiful system of chemical symbols has been formed which greatly facilitates the study of the innumerable complex substances that have to be investigated. Each element is indicated either by one or two letters, being the initial letter, or some two characteristic letters, of its chemical name, so that nearly seventy elements are thus clearly defined.

10. But these symbols represent not only the element, but a definite proportional weight—the atomic weight. Thus H means a unit weight of hydrogen; C means twelve times that weight of carbon; Fe

(ferrum) means fifty-six times that weight of iron. Hence the symbol for any compound substance tells us in the most compact form possible, not only the elements of which it is composed, but the exact proportions in which these elements are combined. Thus C_2H_6O is the chemical symbol for pure alcohol, showing that it is a compound of two atoms of carbon, six of hydrogen, and one of oxygen.

92. SIR HUMPHRY DAVY

11. Looking now at a table of atomic weights, we find that this gives us 24 carbon, 6 hydrogen, and 16 oxygen in each 46 parts of alcohol. By means of these symbols, and the accurate determination of atomic weights, all the complex combinations and decompositions that occur during the investigations of the chemist can be represented in a kind of chemical algebra, and the peculiar formulæ thus obtained often suggest further experiments leading to new discoveries.

12. Almost at the same time that Dalton was working at his atomic theory, Davy (afterwards Sir

Humphry Davy) made the remarkable discovery of two new elements by decomposing soda and potash by means of an electric current, resulting in the production of the metals sodium and potassium. This placed in the hands of chemists a powerful agent which led to the discovery of other elements, though in this respect it has been surpassed by spectrum analysis, which is equally effective in the domains of chemistry and astronomy.

LESSON 36

ELEMENTS AND ATOMS (2)

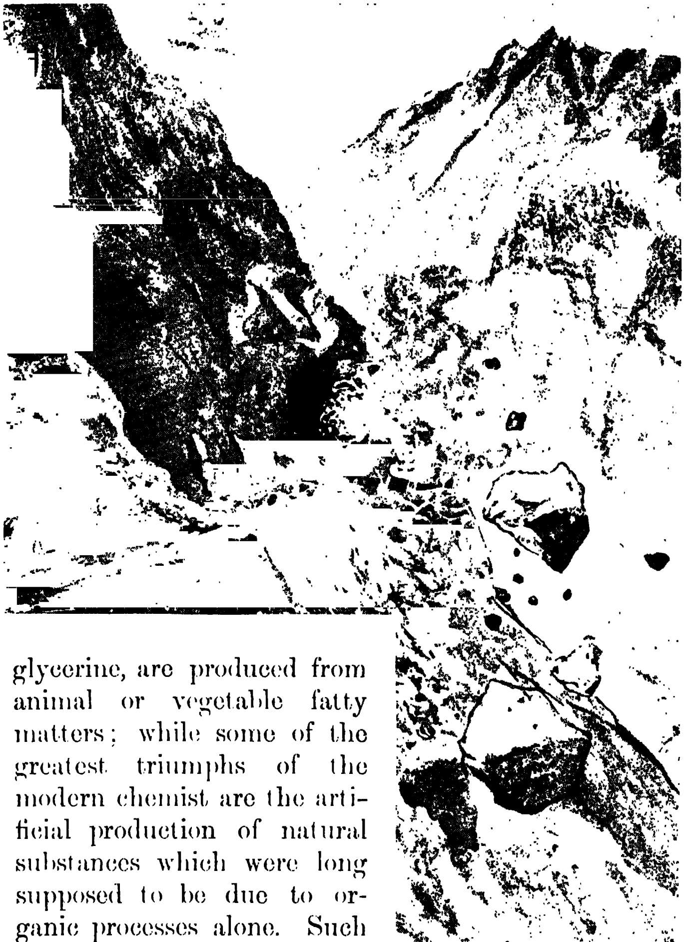
"It is glorious to find out for oneself; but do you call that less yours which has been happily discovered by others and is joyfully recognised and valued by you?"—GOETHE.

1. Among the more interesting discoveries of modern chemistry are the methods of liquefying the various gases, and even solidifying many of them; while by means of the intense heat of the electric furnace all the solid elements can be melted and many vaporised, leading to the conclusion that all matter can exist in the three states—solid, liquid, and gaseous—according to the degree of heat to which it is exposed.

2. The highly complex constitution of various organic products—albumen, fat, gums, resins, acids, oils, ethers, &c.—is the subject of organic chemistry, the study of which has led to some of the most popularly interesting discoveries.

3. Coal-tar has furnished us with a wonderful series of colouring matters, such as the aniline and other dyes; while, from the same material, are produced benzol, carbolic acid, naphtha, creosote, artificial quinine, and saccharine, a substitute for sugar.

4. The new explosives, such as dynamite and nitro-



93. DYNAMITE BLASTING IN A MARBLE QUARRY (CARRARA)

glycerine, are produced from animal or vegetable fatty matters; while some of the greatest triumphs of the modern chemist are the artificial production of natural substances which were long supposed to be due to organic processes alone. Such are the dye indigo, citric acid, urea, and many others.

5. The most recent great advance in the philosophy of chemistry is exhibited

in the views of the Russian chemist, Mendeleef, as to the natural arrangement of the elements, with certain deductions from it.

6. The whole of the best known elements form eight groups, placed in vertical columns, depending on certain similarities in their powers of chemical combination. These are further arranged in twelve horizontal series, in which the atomic weights are most nearly alike, while increasing regularly from the first to the eighth group.

7. In the table thus formed there are certain gaps in the regular order of increase of atomic weights, as if some elements were wanting, while in other cases the place of an element due to its atomic weight did not accord with that dependent on its chemical properties. But the general symmetry of the whole arrangement was such that Mendeleef predicted the future discovery of elements to fill the gaps, and named the chemical and physical properties of these unknown elements.

8. In a few years three new elements were discovered—gallium, scandium, and geranium—and they precisely filled up three of the gaps in the system. Further research as to the atomic weights of the elements that did not fit into the scheme showed that errors had been made, that of uranium being much too low, while in the cases of gold, tellurium, and titanium it was too great.

9. The remarkable success of these predictions—a success always considered the best proof of the truth of a theory—renders it almost certain that the true relations of the elements have now been approximately ascertained, while it strengthens the belief of those who think that what we term elements are not really so, but that their differences depend on special modes

94. A LYDDITE SHELL BURSTING AT MAGERSFONTEIN

of aggregation of a few simple atoms, whose cohesion is so strong that we are not yet, and perhaps never shall be, able to overcome it.

10. It is therefore by no means impossible, perhaps not even improbable, that methods will be discovered of either breaking up some of the elements and producing new elements which are common to two or more of them, or of solving the problem which occupied the alchemists of the Middle Ages—the transmutation of some of the inferior metals into gold.

11. A few years ago a well-known American chemist declared that he had solved the problem of producing gold out of silver at a comparatively small cost, and that when he had made a few millions by his process he would make it known; but he has not yet done so. Twenty years ago this claim would have been scouted as that of a dreamer, but at the present day it is, if true, less unexpected than was the discovery of the marvellous powers of what are termed the Röntgen rays.

12. This very imperfect sketch of the progress of chemistry during the past century would seem to show that this science has not furnished discoveries of such a striking character as those in the domain of physics. But this is apparent only; for some of its important discoveries and generalisations cannot be made intelligible to those who have not a considerable knowledge of the subject, while there are others which have been already described in our earlier chapters. Such popular and useful inventions as gas-illumination, lucifer matches, and all the wonders of photography are essentially applications of chemistry; and the last of these, in its marvellous results, both in the arts and in its various applications to astronomical research, is not surpassed by the achievements of any other department of science.

LESSON 37

ADVANCES IN ASTRONOMY

"The wilder'd mind is tost and lost,
O sea, in thy eternal tide;
The reeling brain essays in vain,
O stars, to grasp the vastness wide!
The terrible, tremendous scheme
That glimmers in each glancing light,
O night, O stars, too rudely jars
The finite with the infinite."

—J. H. DELL.

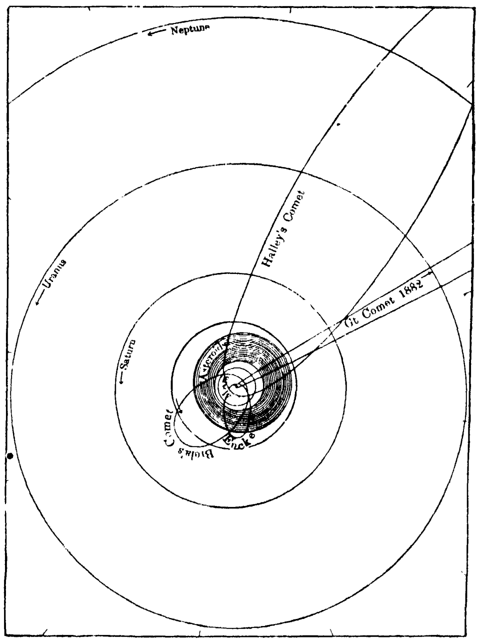
1. Some of the most striking discoveries in this science have been already described under Spectrum Analysis; but there remain a few great advances, due either to observation or to theory, which are of sufficient popular interest to demand notice in any sketch, however brief, of the scientific progress of the past century.

2. With the single exception of Uranus, discovered by Herschel in 1781, no addition had been made to the five planets known to the ancients till the commencement of the present century, when Cēres, the first of the minor planets, was discovered in 1801, and three others between that date and 1807. No more were found till one was added in 1845, and another in 1847. Since that time no year has passed without the detection of one or more new planets belonging to the same system, till their number at the end of the century exceeded 450.

3. These small bodies form a kind of planetary ring situated between Mars and Jupiter, where it had long been suspected a planet ought to be found, because the distance between these older planets was so great as to be quite out of proportion with the

regular increase of distance maintained by the other members of the system.

4. It was at first thought that these asteroids or minor planets were the shattered remains of a much larger one; but our present extended knowledge of the constitution of the solar system renders it more probable that they really constitute a ring of matter

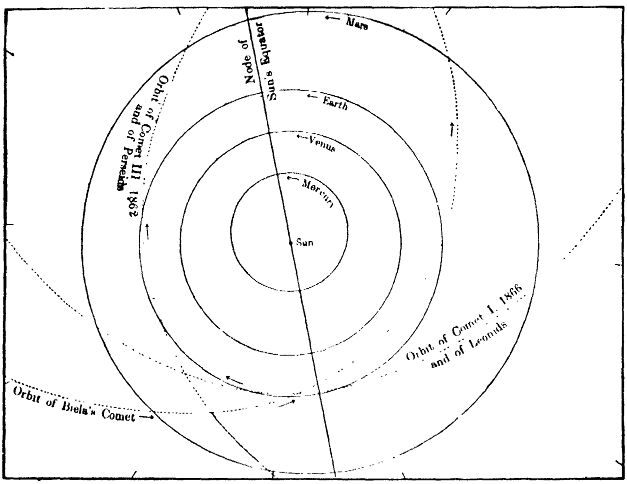


95. THE SOLAR SYSTEM

thrown off by the sun during its progressive contraction; and that some peculiar conditions have prevented its various parts from aggregating into a single planet. This is rendered more probable by two other remarkable discoveries relating to meteors

and comets, and to Saturn's rings, which will be discussed later on.

5. The next large planet added to our system is especially interesting, as affording a striking demonstration of the theory of gravitation, and a no less



96. THE INNER PLANETS

striking example of the powers of modern mathematics. It had been found that the motions of Uranus were not exactly what they ought to be, if due solely to the attraction of the sun and the disturbing influence of Jupiter and Saturn, and it was thought possible that there might be another planet beyond it to cause these irregularities.

6. In the year 1843 a young Cambridge student (John Couch Adams), of the highest mathematical ability, determined to see whether it was not possible to prove the existence of such a planet; and having taken his degree as Senior Wrangler, he at once

devoted himself to the work, and, after two years of study and calculation, he was able to declare that a planet which would account for the perturbations of Uranus must, if it existed, be at that time in a certain part of the heavens, and he sent his calculations on the subject to the Astronomer-Royal in October 1845.

7. By an extraordinary coincidence, a French astronomer (Leverrier) had been for some years working out the motions of the various planets, and in doing so had also reached the conclusion that there must be another unknown body to produce the perturbations of Uranus, which were at that time unusually large. His calculations and results were published at Paris in November 1845 and June 1846, and he gave a position for the unknown planet differing only one degree from that given by Adams.

8. On reading these papers, and seeing the agreement of two independent workers, the Astronomer-Royal asked Professor Challis of the Cambridge Observatory to search for the planet, and on doing so he actually observed it on August 4, and again on August 12; but having no accurate chart of that part of the heavens, he could not be sure that it was not a small star. A month later, it was found and identified at Berlin, from information furnished by Leverrier.

9. It thus appears that Adams first privately announced the position of the new planet, and that it was first observed at Cambridge; while the somewhat later announcement by Leverrier and discovery at Berlin were first made public, and thus gained the honours of priority. The two discoveries were, however, practically simultaneous and independent, and the names of Adams and Leverrier should for ever be jointly associated with the planet Neptune.

LESSON 38

OTHER PLANETARY DISCOVERIES

"Then felt I like some watcher of the skies,
When a new planet swims into his ken."
—KEATS.

1. Several other important discoveries in the planetary system are due to the increased power of modern telescopes and the greater number of observers.

2. In 1877, two minute satellites of Mars were discovered at Washington by means of the large telescope with a 25-inch object glass, then the largest in the world. These are remarkable in being exceedingly small, and very close to the planet. They are said to be only six or seven miles in diameter, and the inner one is only about 5800 miles from the centre or 3800 from the surface of the planet, around which it revolves in less than eight hours; while the outer one is about 14,500 miles away, and revolves in a little more than thirty hours.[1]

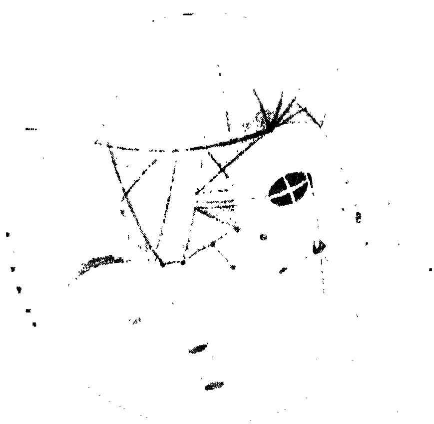
3. Still more recently (in September 1892), a fifth satellite of Jupiter was discovered by means of the great Lick telescope in California. This also is very small and very close to the planet, being less than half the diameter, or about 40,000 miles from its surface.

4. Another very remarkable discovery is that of a

[1] In "Gulliver's Travels," published in 1726, Swift describes the astronomers of Laputa as having "discovered two lesser stars, or satellites, which revolve around Mars; whereof the innermost is distant from the centre of the primary planet exactly three of his diameters, and the outermost five; the former revolves in the space of ten hours, and the latter in twenty-one and a half." This is a wonderful anticipation, especially as to time of revolution, and if we substitute "radii" for "diameters," the distances are also very near.

system of symmetrical markings, covering a large part of the surface of Mars. They consist of a series of triangles or quadrilaterals bounded by straight lines, which are sometimes seen double, at other times single, or are even altogether invisible.

5. Another peculiar feature is that where these canals (as they are termed) intersect there is always a black circular spot, very distinct, and unlike any mark-



97. MARS, SHOWING THE MARKINGS OR "CANALS"

ings upon other parts of the surface. It is a curious fact that the double canals sometimes enclose a space of more than a hundred miles wide and several hundred long, adding to the appearance of artificiality.

6. Sometimes no canals are seen, but they come into view as the polar snows begin to melt; hence the suggestion that they really indicate great channels

constructed to carry off the water from the rapidly-melting snow and distribute it by irrigation-ditches over the adjacent land, which, being rapidly covered with vegetation, causes the change of colour which renders them visible.

7. These observations were made by Schiaparelli at Milan in 1877, and were confirmed by Mr. Percival Lowell in 1894, at his observatory in Arizona, where the purity of the atmosphere renders it possible to observe details which are elsewhere rarely visible. If future observations should confirm the views as to the artificial nature of these features of the surface of the planet which most nearly resembles our earth, it must be considered to be the most sensational astronomical discovery of the nineteenth century, and that which opens up the most exciting possibilities as to communication with beings who are sufficiently advanced to execute such widespread and gigantic irrigation works.

8. The ring around the planet Saturn was long supposed to be single, and to be solid like the planet itself; but with improved telescopes it was found to be double, and with still finer instruments to consist of an indefinite number of rings close together, one of them being very obscure, as if formed of nebulous matter.

9. In the year 1859, Clerk-Maxwell, by a profound mathematical investigation, proved that either solid or liquid rings would be unstable, and would inevitably break up so as to form a number of satellites; and he concluded that the rings really consisted of a crowd of small bodies so near together as to appear like a solid mass; and as the appearance of the rings, and some slight changes detected in them, were in harmony with this view, it has been generally accepted.

10. But quite recently the wonderful instrument, the spectroscope, has given the final demonstration that this theory is correct. If the rings are solid, it is clear that a point on the outer edge must move more rapidly than one on the inner edge; whereas, if they consist of separate particles, each revolving independently round the planet, then, in accordance with the laws of all planetary motions, those forming the inner side of the rings, being nearer to the planet, must move much quicker than those on the outer side.

98. SATURN

11. As already explained in Lesson 22, the spectroscope enables us to measure motion in the line of sight—that is, towards or away from us—of any heavenly bodies, and by observing the outer extremities of the rings to the right and left of the planet, where the motion is, of course, in these two directions, it is found that the motion of the inner edge is considerably more rapid than that of the outer edge, showing that those parts move round the planet independently, and are therefore formed of separate particles or small masses.

12. These observations were made by the American astronomer, Professor James E. Keeler, in 1895, and are of extreme delicacy; but that they are trustworthy is shown by the fact that the resulting velocities are in accordance with Kepler's third law, which determines the relative motions of all planetary bodies at varying distances from the primary.

LESSON 39

METEORS AND METEORITES

"The bay-trees in our country are all withered,
And meteors fright the fixed stars of heaven."
—SHAKESPEARE.

99. FIRE-BALLS (Sept. 7, 1875)

1. A still more important discovery is that which has explained, by one consistent theory, the various phenomena presented by aërolites, fire-balls, and shooting or falling stars, now generally classed as meteors and meteorites; and this theory is found to have an important bearing on the constitution of the solar system, and perhaps even on that of the whole stellar universe.

2. Although there are records of the fall of solid stones from the sky in the works of Greek, Chinese, and European authors, from 654 B.C. down to our times, while the astronomer Gassendi in the year 1627 himself witnessed the fall

of a stone weighing 59 lbs. in the South of France, yet the phenomenon was so rare and so inexplicable, that it was often disbelieved.

3. One philosopher is reported to have disposed of the whole matter by saying, "There are no stones in the sky, therefore none can fall from it." But the evidence for such falls soon became overwhelming, and their connection with fire-balls and shooting stars was also well established.

4. One of the most remarkable of modern meteors was that seen at Aigle, in Normandy, on April 26, 1803. About 1 P.M. a brilliant fire-ball was seen traversing the air at great speed. A violent explosion followed, apparently proceeding from a small lofty cloud. This was no doubt the product of the explosion, which would become visible long before the sound was heard; and then came a perfect shower of stones, nearly three thousand being picked up, the largest weighing 8 lbs.

100. METEOR (Nov. 27, 1877)

5. A still more extraordinary meteor was seen on March 19, 1719, about eight o'clock in the evening, in all parts of England, Scotland, and Ireland. In London, it appeared like a ball of fire as large as the moon; at Exeter, the light was like that of the sun. It was followed by a broad stream of light, and burst with a report like that of a cannon, with a great display of red sparks like a huge sky-rocket;

but as it was then over the sea, between Devonshire and the coast of Brittany, its fragments were not recoverable. Dr. Whiston, Newton's successor as Professor of Mathematics at Cambridge, who published an account of it, calculated its height over London as fifty-one miles, and over Devonshire thirty-nine miles.

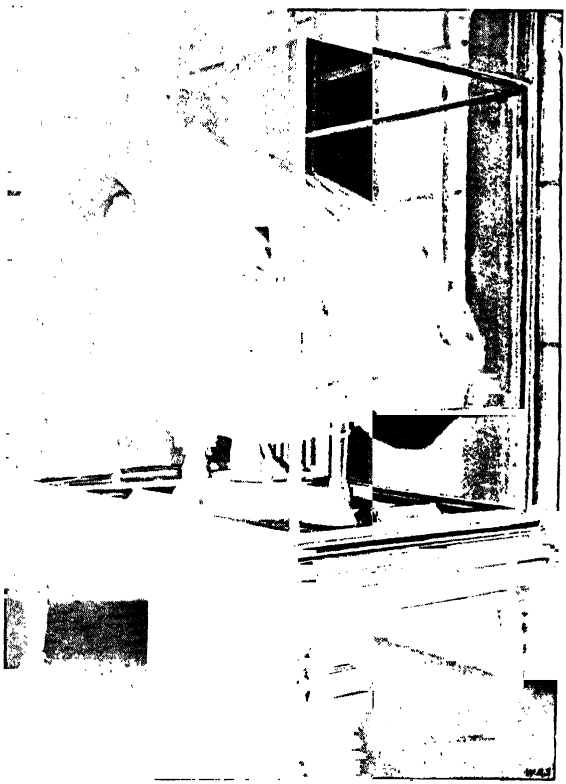
6. Falling stars, sometimes seen singly, at other times in considerable numbers, as well as the less frequent but larger fire-balls above described, appeared to be connected phenomena, although little was really known about them till the early part of this century, when they began to be more carefully studied. By observations of the same meteor or fire-ball at distant localities, its altitude and the velocity with which it moved were ascertained, and these were always found to be so great as to show that these objects could not have a terrestrial origin.

7. It was soon observed that showers of falling stars occurred about the same time every year, with displays of great brilliancy at long intervals, and on these occasions the meteors all appeared to radiate from certain definite points in the sky. Thus in November they seem to originate in the constellation Leo, and in August in Perseus, while others apparently belong to distinct constellations.

8. The only way of explaining these appearances seemed to be that there were streams of small bodies travelling in elliptic orbits round the sun, and that the earth crossed these orbits at fixed points once a year. Then a number of these small bodies, many of them perhaps no larger than pebbles or grains of sand, coming into our atmosphere, became heated, and even vaporised, by the friction due to their rapid planetary motion, and appeared to us as shooting stars; while

larger masses, whose interior alone became heated, either exploded or fell entire as meteorites.

9. The exceptional displays of the November meteors at intervals of about thirty-three years is due to the



101. THE LARGEST METEORITE IN ENGLAND (WEIGHING 3½ TONS)

fact that the stream is much denser in this part of its orbit, where the meteoric matter may be slowly aggregating to form a planetary body.

10. A large number of such meteor-streams have

now been observed; but the most remarkable discovery is, that in some cases, and probably in all, comets form a part of such meteoric streams. This has been proved by showing that the orbits and times of revolution of certain comets coincide exactly with those of meteor-streams as independently observed.

11. Thus, Tempel's comet, seen in 1866, coincides with the November meteors or Leonids; Biela's comet, with the Andromeda meteors; while the bright comet of 1862 coincides with the August Perseids. Seventy such cases of the association of comets and meteor-streams are now known; and Sir Norman Lockyer has completed the proof of the connection by showing that when fragments of meteoric stones are intensely heated in a vacuum they afford a spectrum closely resembling those of comets.

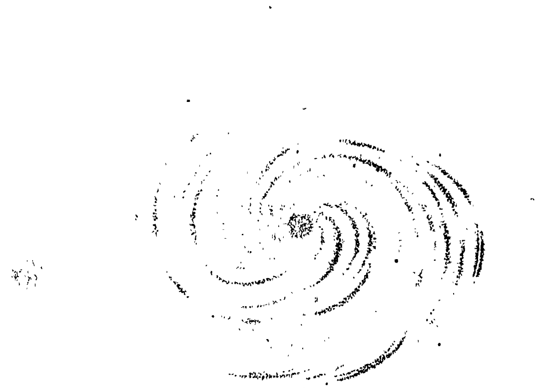
12. Some meteors are visible every fine night, and it has been calculated by Professor Newton of Yale College that seven and a half millions enter the earth's atmosphere every day; and if we add to these, the much greater number that must escape observation, it is supposed that the actual number may be several hundred millions.

13. Of course, it is only by a kind of accident that the orbit of our earth crosses any of these meteoric streams, so that there are certainly a vast number, perhaps thousands or even millions, of such streams in the solar system, since some hundreds are either known or suspected to cross our path.

14. Taking into consideration these numerous meteor-streams moving in elliptic orbits round the sun, together with the vast number of stray meteors, as it were, indicated by those that are seen every day in the year, and by the exceptionally large and rare fire-balls, we are led to the conclusion that the space

occupied by the solar system, instead of being almost empty, as formerly supposed, is really full of solid bodies varying in size from that of dust or sand-grains up to huge masses a thousand times that of our earth.

LESSON 40



102. SPIRAL NEBULA IN CANES VENATICI

THE METEORITIC THEORY

"I see thy glory like a shooting star
Fall to the base earth from the firmament."
—SHAKESPEARE.

1. The eight major planets are so remote from each other, that if we represent the solar system as an open plain two and a half miles in diameter, our earth will in due proportion be shown by a pea, Mars by a large pin's head, Jupiter by an orange, and Neptune

on the extreme outer edge by a largish plum. From any one of them the nearest would be invisible to us unless brilliantly illuminated; and however smooth and open was the plain, we might walk across it again and again in every direction, and, with the exception of the two-foot ball in the centre representing the sun, we should probably declare it to be absolutely empty.

2. Looking thus at the solar system, the vast emptiness, the absurd disproportion of the sizes of the planets to the immense spaces around and between them, was almost oppressive; and even when we took account of the nebular hypothesis, and tried to imagine a mass of elemental gaseous matter occupying a sphere of the diameter of the orbit of Neptune, gradually cooling and shrinking, leaving rings of diffused matter behind it, which afterwards broke up and aggregated into the planets and satellites already known to us, the hypothetical solution of the problem was hardly satisfying, since it seemed difficult to understand how so vast a *plenum* could be converted into an equally vast *vacuum*, except for the few and remotely scattered planetary systems as its sole relics.

3. But the study of the long-despised and misunderstood meteorites and falling stars has entirely changed our conceptions of that portion of the universe of which our sun is the centre. We are now led to regard it as more nearly approaching a plenum than a vacuum.

4. We know that it is everywhere full of what may be termed planetary and meteoric life—full of solid moving bodies forming systems of various sizes and complexities, from the vast mass of Jupiter with its five moons, down to some of the minor planets a few miles in diameter, and just large enough to become

visible by reflected light, and again, downward, of all lesser dimensions to the mere dust-grains which only become visible when the friction on entering our atmosphere with the great velocities due to their planetary motion round the sun ignites and sometimes, perhaps, dissipates them.

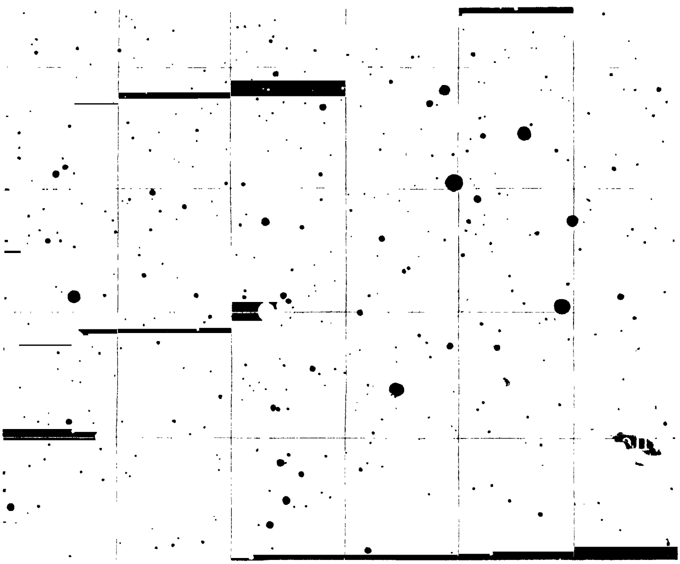
5. We here obtain a new conception of the possible origin of the universe as we now see it (a conception which originated with Professor Tait, and has been forcibly advocated by Lockyer and a few other astronomers), which is, that both the solar system and the stellar universe have arisen from the aggregation of widely diffused solid particles, molecules, or atoms, whose coming together under the influence of gravitation produces heat, incandescence, and sometimes elemental vaporisation, rather than from a primitive cosmic vapour from which solid masses have been formed by cooling and contraction.

6. Everywhere we become aware of these solid masses of various sizes occupying the spaces around us. The rings of Saturn are composed of such solid particles in a state of unusual condensation. The vast ring of the minor planets indicates probably the existence there of millions of smaller invisible bodies forming a stream of meteors, analogous to some of those which cross our orbit.

7. Then we have the comets, consisting of a dense swarm of such meteors whose frequent collisions may produce the luminous gases indicated by their spectra. Yet further, the strange zodiacal light, extending from the sun beyond the earth's orbit, is now supposed to be due to the light reflected under favourable conditions from the finest particles driven from the sun's corona by electrical repulsion.

8. In its wider application to the stellar universe,

the same theory serves to explain phenomena once supposed to be radically distinct. There is now known to be a perfect gradation from the faintest and least condensed nebulæ to the most brilliant stars, and these are all explained, on what is termed the meteoritic hypothesis, as being different stages in



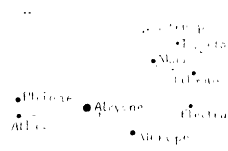
103. THE PLEIADES AS PHOTOGRAPHED

the aggregation of meteoritic matter everywhere and always going on.

9. From the faintest diffused nebulæ we pass to those which exhibit a radial or spiral mode of condensation, and to others which possess a dense nucleus like a comet; then we have the compact discs called planetary nebulæ, and others which seem to be aggregated around one or more bright stars.

10. Recently it has been found that many stars—

among others those of the Pleiades, which even in the most powerful telescopes appear like ordinary stars—are really nebulous stars when photographed with very long exposure under conditions such as those which exhibit many thousands of stars which no telescope can render visible. And when these various bodies are examined with the spectroscope, they are seen to have many features in common, such as indicate differences in temperature, and consequent difference in the amount and character of the luminous gases due to their greater or less condensation.



104. THE PLEIADES

11. The nebulæ of various forms and intensity are therefore believed to show us the early stages in the development of stars, suns, and planetary systems out of diffused meteoritic matter; while stars themselves are of various temperatures, the heat increasing when the meteoritic matter is most rapidly aggregating, and afterwards cooling till they become of so low a temperature as to cease to be luminous to our vision, as is the case with the dark companions of some of the spectroscopic double stars.

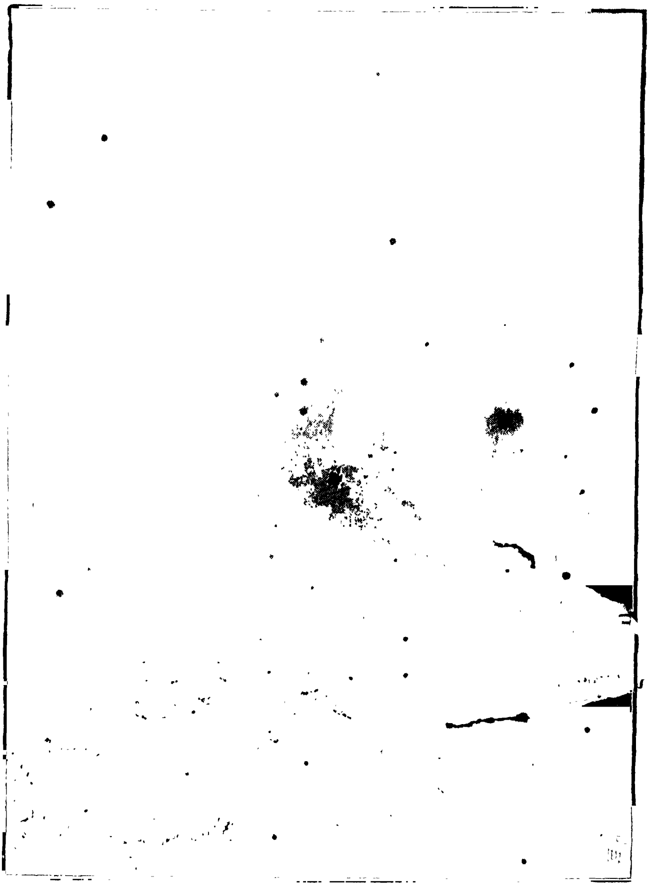
LESSON 41

ORIGIN OF THE UNIVERSE

"From what beginning, what fire-fountain hurled,
Burst the bright streams, and every spark a world."
—F. W. H. Myers.

1. This conception of the meteoritic constitution of the whole stellar universe is one of the grandest

achievements of the science of the Nineteenth Century.



105. THE GREAT NEBULA IN ORION

(Visible to the naked eye, and a very beautiful object when observed with a small telescope or opera-glass)

All the other astronomical discoveries of the period (except those gained through the spectroscope) are

additions to our knowledge of essentially the same nature as others which preceded them; but in this case we have a new and comprehensive generalisation linking together a vast host of phenomena which, till quite recently, were isolated or misunderstood.

2. Beginning with the meteoritic masses which at considerable intervals fall upon the earth, and the meteoric or cosmic dust which in minute spherules is probably always falling—since it is found abundantly in all the deepest oceanic deposits far removed from continental land—we have next the meteor-streams with their attendant comets, circling round the sun in every direction, and probably numbering many thousands, since we only know those which chance to enter our atmosphere; then come the asteroids, ever increasing in recorded numbers, and probably forming the larger members of a vast meteor-ring; and the rings of Saturn, now proved to be of the same meteoritic nature.

3. Then, passing on to the interstellar spaces, we find the nebulæ, which are but vast uncondensed meteor-clouds; the planetary nebulæ and nebulous stars being examples of greater condensation, leading on to the myriads of the starry hosts, each one a sun heated by the inward rush and titanic collisions of countless meteor-swarms.

4. These suns, after reaching a maximum of heat and light, slowly cool into darkness, until a collision with other cosmic matter again heats the mass to incandescence, or even to vaporisation—all this grand series of phenomena, rising from dust-particles on the ocean bed to a million million of suns, comprehended, and to some extent explained, by one of the simplest and at first sight most inadequate of hypotheses—that of a meteoritic origin of the material universe.

5. It has been objected that this theory is not so

simple as the old nebular hypothesis, and has no advantages over it.

6. But this is a mistake. The latter begins with what we now see to be an impossible condition—that of a universe in a state of vapour. For all matter, in the absence of heat, is solid; and the only sources of heat we know of are impact or friction, and chemical combination, including electric action. Heat, therefore, in all its degrees and manifestations, will necessarily arise from diffused solid matter subject to gravitation, but it will arise partially and locally, not universally; and we now know that there *are* such varieties of temperature in the stellar universe.

7. We have also positive evidence of solid matter everywhere, in an almost infinite gradation of size and of temperature, from that amount of cold in which no liquid, and perhaps no gas, can exist, up to that amount of heat in which all the elements are vaporised.

8. We *can* conceive how, from diffused solid matter, without heat, the actual condition of the universe may have arisen; but we *cannot* conceive any previous condition which would result in the universal vaporisation of all matter which the nebular hypothesis presupposes.

9. But this grand meteoritic theory, like all possible theories or speculations as to the origin of the cosmos, only takes us one step backward, and then leaves us no whit nearer to a real comprehension of the great insoluble problem.

10. For we ask whence came this inconceivably vast extension of meteoric matter? What was its antecedent state? How did matter, at first presumably simple or atomic, aggregate into those forms we know as elements? And even if we could get back to a universe of primitive atoms, we should still be no

nearer a complete solution, for then would begin a new series of questions far more difficult to answer.

11. We should begin to seek after the origin of the FORCES which caused the development of atoms into matter and into worlds. Whence the simplest cohesive forces? Whence the chemical forces? Whence the all-pervading electric forces? And, more mysterious than all, whence the force of gravitation, infinite, unchangeable, and at the very root of cosmic development?

12. Beyond these problems again, and quite as essential and insoluble, are the problems of the ether. What is the ether, and what are its relations to matter? Whence the forces that cause the ether to vibrate, and, in the various forms of heat, light, or electricity, to be the source of all change of form, all molecular motion, all those infinite modifications in the states of matter that alone seem to render possible the development of organised living forms?

13. To all these questions we have no definite answers, and probably never shall have any that are at all satisfactory. We must be content with obtaining some definite knowledge of the condition of the visible universe before it reached the stage in which we now find it; and must accept the fact that any knowledge of the beginning of things is beyond the capacity of human intelligence. The final conclusion of the greatest thinker of the Nineteenth Century—Herbert Spencer—is, "that all we know of the universe and its laws forces upon our minds the consciousness of an Inscrutable Power manifested through all phenomena."

LESSON 42

ADVANCES IN GEOLOGY

"The hills are shadows, and they flow
From form to form, and nothing stands;
They melt like mist, the solid lands,
Like clouds they shape themselves and go."

—TENNYSON.

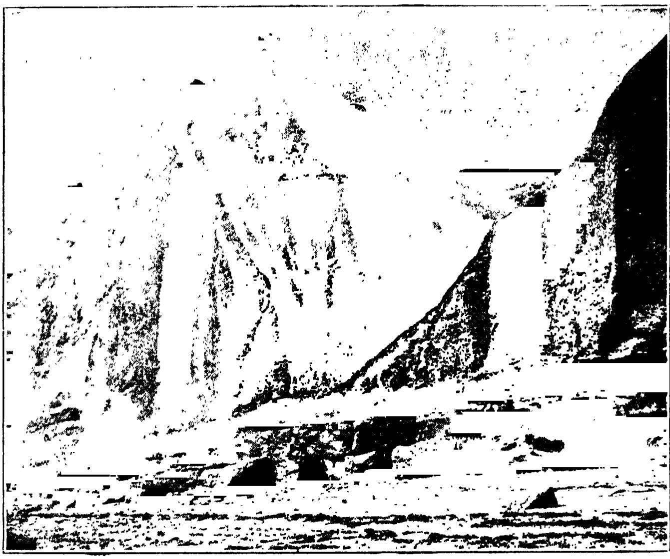
1. The foundations of modern geology were laid in the latter part of the eighteenth century by Werner, Hutton, and William Smith, but most of the details and some of the more important principles have been wholly worked out during the nineteenth century.

2. The great landmarks of its progress can alone be referred to here, namely (1) the establishment by Lyell of what has been termed the Uniformitarian theory; (2) the proof of a recent Glacial epoch and the working out of its effects upon the earth's surface; and (3) the discovery that Man in the northern hemisphere lived contemporaneously with many now extinct animals.

3. In the early part of the century, and so late as the year 1830, Cuvier's "Essay on the Theory of the Earth" held the field as the exponent of geological theory. A fifth edition of the English translation appeared in 1827, and a German translation so late as 1830.

4. In this work it was maintained that almost all geological phenomena pointed to a state of the earth and of natural forces very different from what now exists. In the raised beds of shells, in fractured rocks, in vertical stratification, we were said to have proofs "that the surface of the globe has been broken up by revolutions and catastrophes."

5. The differences in the character of adjacent stratified deposits showed that there must have been various successive irruptions of the sea over the land; and Cuvier maintained that these irruptions and retreats of the sea were not slow or gradual, "but that most of the catastrophes which have occasioned them have been sudden."



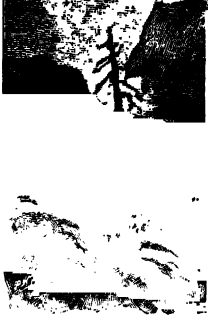
106. CLIFFS OF BOULDER CLAY RESTING ON UPPER OOLITE

(Showing peaks produced during the human epoch by atmospheric agencies)

6. He urged that the sharp and bristling ridges and peaks of the primitive mountains "are indications of the violent manner in which they have been elevated"; and he concludes that "it is in vain we search among the powers which now act at the surface of the earth for causes sufficient to produce the revolutions and

catastrophes, the traces of which are exhibited in its crust."

7. This theory of convulsions and catastrophes held almost universal sway within the memory of persons now living, for although Hutton and Playfair had advanced far more accurate views, they appear to have made little impression, while the great authority attached to Cuvier's name carried all before it.

107. AIGUILLES NEAR MONT BLANC

8. But in 1830, while Cuvier was at the height of his fame, and his book was still being translated into foreign languages, a hitherto unknown writer published the first volume of a work which struck at the very root of the catastrophic theory, and demonstrated by a vast array of facts and the most cogent reasoning, that almost every portion of it was more or less imaginary and in opposition to the plainest teachings of nature. The victory was

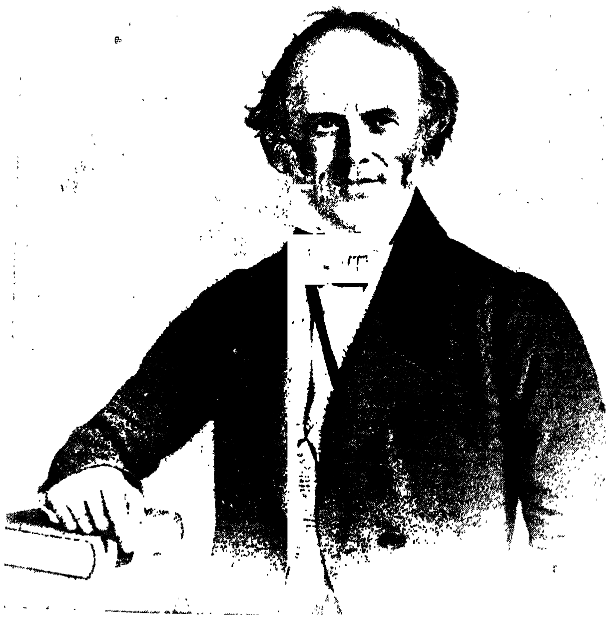
complete. From the date of the publication of the "Principles of Geology" there were no more English editions of "The Theory of the Earth."

9. Lyell's method was that of a constant appeal to the processes of nature. Before asserting that certain results could not be due to existing causes, he carefully observed what those causes were now doing.

10. He applied to them the tests of accurate measurement, and he showed that, taking into account the element of long-continued action, they were, in almost every case, fully adequate to explain the observed phenomena.

11. He showed that modern volcanoes had poured out equally vast masses of melted rock, which had covered equally large areas, with any ancient volcano, that strata were now forming comparable in extent and thickness with any ancient strata; that organic remains were being preserved in them, just as in the older formations; that land was almost everywhere either rising or sinking as of old; that valleys were being excavated and mountains worn away; that earthquake shocks were producing faults in the rocks; that vegetation was now preparing future coal-beds; that limestones, sandstones, metamorphic and igneous rocks were still being formed; and that, given time and the intermittent or continuous action of the causes we can now trace in operation, all the contortions and fractures of strata, all the ravines and precipices, and every other modification of the earth's crust supposed to imply the agency of sudden revolutions and violent catastrophes, may be again and again produced.

LESSON 43



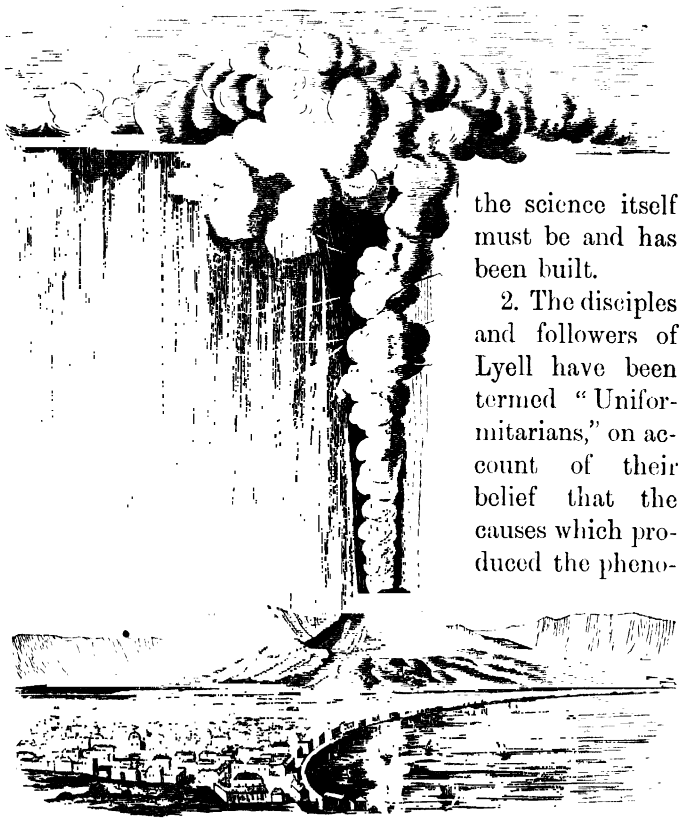
108. SIR CHARLES LYELL

GEOLOGICAL FORCES (1)

"O earth, what changes hast thou seen!
There where the long street roars, hath been
The stillness of the central sea."—TENNYSON.

1. During a period of more than forty years, Sir Charles Lyell continued to enlarge and improve his work, bringing out eleven editions, the last of which was published three years before his death; and rarely has any scientific work so completely justified its title,

since it remains to this day the best English exposition of the "Principles of Geology"—the foundation on which the science itself must be and has been built.

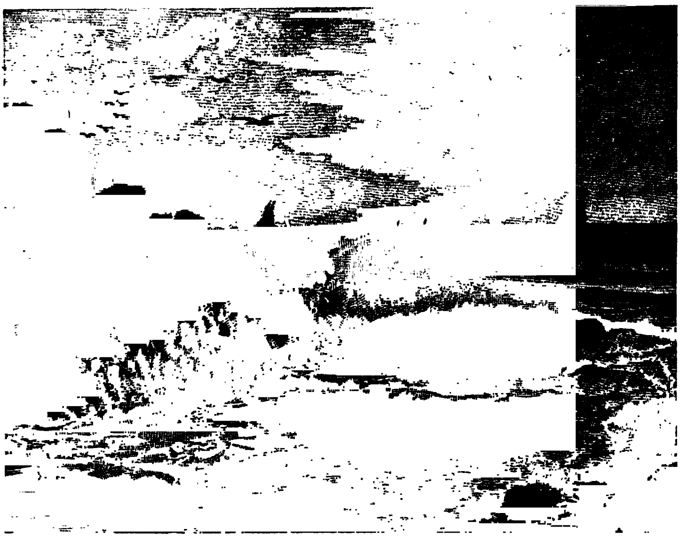


2. The disciples and followers of Lyell have been termed "Uniformitarians," on account of their belief that the causes which produced the phenomena manifested to us in the crust of the earth are essentially of the same nature as those acting now; and, as is often the case, the use of the term as a nickname has led to a misconception as to

109. EXAMPLE OF IGNEOUS ACTION
(Vesuvius in Eruption)

the views of those to whom it is applied. A few words on this point are therefore called for.

3. Modern objectors say that it is unphilosophical to maintain that in our little experience of a few hundred, or at most a few thousand years, we can have witnessed all forms and degrees of the action of natural forces; that we have no right to take the



110. EXAMPLE OF AQUEOUS ACTION
(Waves destroying hard rocks on Cornish Coast)

historical period as a fair sample of all past geological ages; and that, as a mere matter of probability, we ought to expect to find proofs of greater earthquakes, more violent eruptions, more sudden upheavals, and more destructive floods having occurred during the vast eons of past time.

4. Now this argument is perfectly sound if limited to the occurrence of extreme cases, but not if applied

to averages. No uniformitarian will deny the probability of there having been *some* greater convulsions in past geological ages than have ever been experienced during the historical period.

5. But modern convulsionists do not confine themselves to this alone, but maintain that, *as a rule*, all the great natural forces tending to modify the surface of the earth were more powerful and acted on a larger scale than they do now. On the ground of mere probability, however, we have no right to assume a diminution rather than an increase of natural forces in recent times, unless there is some proof that these forces have diminished. Sir Charles Lyell shows that the cases adduced as indicating greater forces in the past are fallacious, and his doctrine is simply one of real as against imaginary forces.

6. But our modern objectors have another argument, founded upon the admitted fact that the earth has cooled and is slowly cooling, and was probably once in a molten condition. They urge that in early geological times, when the earth was hotter, the igneous, aqueous, and aërial forces were necessarily greater, and would produce more rapid changes and greater convulsions than now.

7. This is a purely theoretical conclusion, by no means sure, and perhaps the very reverse of what really occurred. There are two reasons for this last-mentioned belief, which may be very briefly stated.

8. After the earth's crust was once formed it cooled very slowly, and the crust became very gradually thicker. So far as the action of the molten interior on the crust may have produced convulsions, they should become not less, but more violent as the crust becomes thicker. With a thin crust any internal tension will be more frequently relieved by fracture or

bending, and the resulting disturbances will be *less* violent; but as the crust becomes thicker and stronger, internal tensions will accumulate, and when relieved by fracture the disturbance will be *more* violent.

9. As regards storms and other aërial disturbances,

111. ANOTHER EXAMPLE OF AQUEOUS ACTION
(Showing the water-worn Chalk Cliffs at Dover)

these also would probably be less violent when the temperature of the whole surface was more uniform as well as warmer, and the atmosphere consequently so full of vapour as to prevent the sun's rays from producing the great inequalities of temperature that now prevail.

10. It is these inequalities that produce the great aërial disturbances of our era, which arise from the

heated surfaces of the bare plains and deserts of the sub-tropical and warm-temperate belts. In the equatorial belt (10° or 12° each side of the equator), where the heat is more uniform and the surface generally well clothed with vegetation, tornadoes and hurricanes are almost unknown.

11. There remains only the action of the tides upon coasts and estuaries, which may have been greater in early geological times, if, as is supposed, the moon was then considerably nearer to the earth than it is now. But this is a comparatively unimportant matter as regards geological convulsions, because its maximum effects recur at short intervals and with great regularity, so that both vegetation and the higher forms of animal life would necessarily be limited to the areas which were beyond its influence.

12. It thus appears that, so far from there being any theoretical necessity for greater violence of natural forces in early geological times, there are some weighty reasons why the opposite should have been the case; while all the evidence furnished by the rocks themselves, and by the contours of the earth's surface, are in favour of a general uniformity, with, of course, considerable local variability.

LESSON 44

GEOLOGICAL FORCES (2)

> "The sound of streams that swift or slow
> Draw down Æonian hills, and sow
> The dust of continents to be."
>
> —TENNYSON.

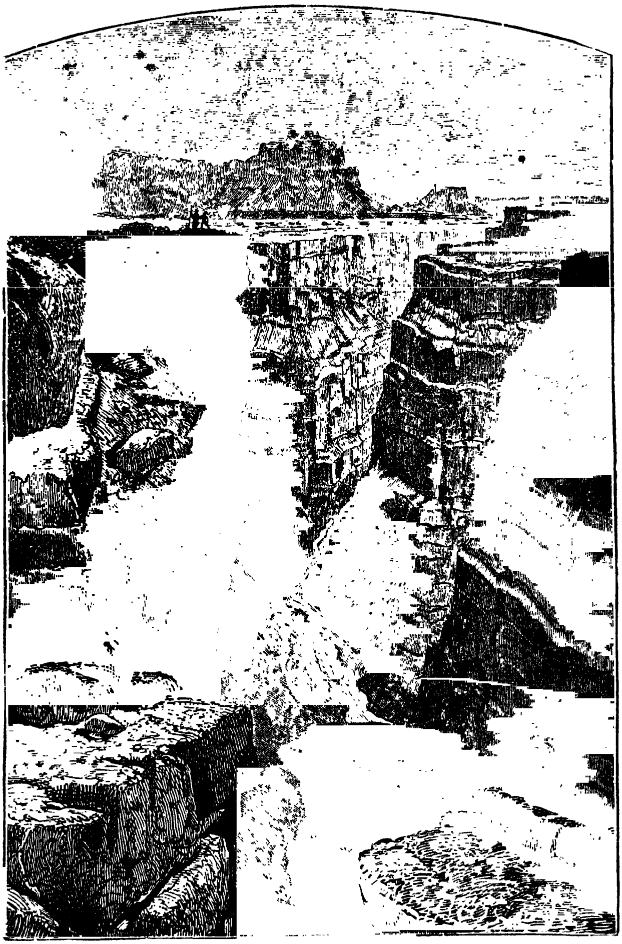
1. It is interesting to note the very different explanations of the commonest features of the earth's surface given by the old and by the new theories. In

every mountain region of the globe deep valleys, narrow ravines, and lofty precipices are of common occurrence, and these were, by the old school, almost always explained as being due to convulsions of nature. In ravines, we were taught that the rocks had been "torn asunder," while the mountains and the precipices were indications of "sudden fractures and upheavals of the earth's crust."

2. On the new theory, these phenomena are found to be almost wholly due to the slow action of the most familiar every-day causes, such as rain, snow, frost, and wind, with rivers, streams, and every form of running water acting upon rocks of varying hardness, permeability, and solubility. Every shower of rain falling upon steep hillsides or gentle slopes, while partially absorbed, to a large extent runs over the surface, carrying solid matter from higher to lower levels. Every muddy stream or flooded river shows the effect of this action.

3. Day and night, month after month, year after year, this denudation goes on, and its cumulative effects are enormous. The material is supplied from the solid rocks, fractured and decomposed by the agency of snow and frost or by mere variations of temperature, and primarily by those interior earth-movements which are continually cleaving, fissuring, and faulting the solid strata, and thus giving the superficial causes of denudation facilities for action.

4. The amount and rate of this superficial erosion and denudation of the earth's surface can be determined by the quantity of solid matter carried down by the rivers to the sea. This has been measured with considerable accuracy for several important rivers; and by comparing the quantity of matter, both in suspension and solution, with the area of the river basin,



112. EXAMPLE OF ATMOSPHERIC ACTION
(Cañon of the Colorado formed by Atmospheric Denudation)

we know exactly the average amount of lowering of the whole surface per annum.

5. It has thus been calculated that—

The Mississippi removes one foot of the surface of its basin in		.	.	.	.	6000	years.
,,	Ganges	,,	,,	,,	,,	2358	,,
,,	Hoang-Ho	,,	,,	,,	,,	1464	,,
,,	Rhone	,,	,,	,,	,,	1528	,,
,,	Danube	,,	,,	,,	,,	6846	,,
,,	Po	,,	,,	,,	,,	729	,,
,,	Nith	,,	,,	,,	,,	4723	,,

6. The average of these rivers gives us one foot in 3000 years, or a thousand feet in three million years as the rate of lowering of the land by sub-aërial denudation; but as Europe has a mean altitude of less than a thousand feet, it follows that at the present rate of denudation the whole of Europe would be reduced to nearly the sea-level in about three million years. Before this method of measuring the rate of the lowering of continents was hit upon by Mr. Alfred Tylor in 1853, no one imagined that it was anything like so rapid; and, as a million years is certainly a short period as compared with the whole geological record, it is clear that elevation must, on the whole, have always kept pace with the two lowering agencies—sinking and denudation.

7. Again, as in every continent the areas occupied by plains and lowlands, where denudation is comparatively slow, are large as compared with the mountain areas, where all the denuding agencies are most powerful, it is probable that most mountain ranges are being lowered at perhaps ten times the above average rate, and many mountain peaks and ridges perhaps a hundred times.

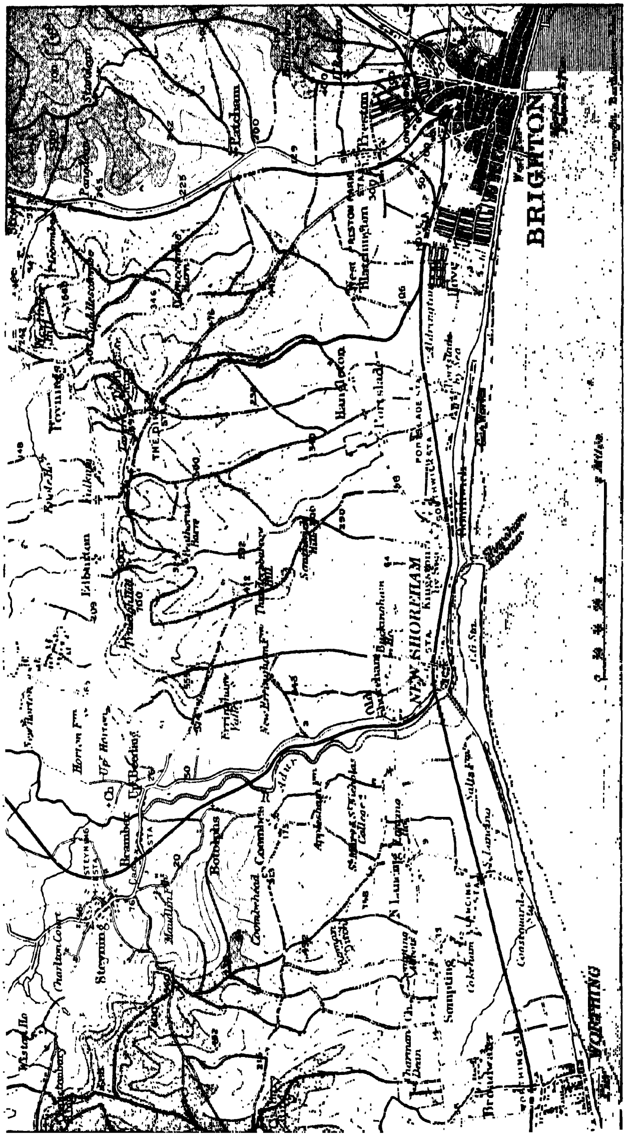
8. Examples of the rapidity of denudation as compared with earth movements are to be found everywhere. In disturbed regions, faults of many hundreds, and sometimes even thousands of feet, are not uncommon; yet there is often no inequality on the surface, indicating that the dislocation of strata has been caused by small and often-repeated movements, at such intervals that denudation has been able to remove the elevated portion as fast as it arose.

9. Again, when the strata are bent into great folds or undulations, it is only rarely that the tops of the folds correspond to ridges and the depressions to valleys. Frequently the reverse is the case, a valley running along the anticlinal line or structural ridge, while the synclinal or structural hollow forms a mountain top; while in other cases, valleys cut across these structural features, with little or no regard to them.

10. This results from the fact that it is not mountains or mountain ranges as we see them which have been raised by internal forces, but a considerable area, already perhaps much disturbed and dislocated by earth-movements, has been slowly raised till it became a kind of tableland.

11. From its first elevation above the sea, however, it would have been exposed to rainfall; and the water flowing off in the direction of least resistance, would have formed a number of channels radiating from the highest portion, and thus establishing the first outlines of a system of valleys, which go on deepening as the land goes on rising, often quite irrespective of the nature of the rocks beneath.

12. This explains the close resemblance in the general arrangement of valleys in all high regions, as well as the very common phenomenon of a river



113. CONTOUR MAP SHOWING THE RIVER ADUR FLOWING THROUGH THE SOUTH DOWNS

(The darkest portions are the most elevated)

crossing the main range of a mountain system by a deep gorge; for this merely shows that what is now the highest part of the range was at first lower than that where the river has its source, but has become higher by the more rapid degradation of the lateral ranges, owing to their being formed of rock which is more easily disintegrated.

13. The various peculiarities of open valley and narrow gorge, of steep mountains or lofty precipice, of rivers cutting across hills, as in the South Downs (see Map) and at Clifton, when open plains by which they might apparently have reached the sea are near at hand, may be all explained as the results of those simple causes which are everywhere in action around us. It was Sir Charles Lyell who first convinced the whole scientific world of the efficacy of these familiar agents; and the secure establishment of this doctrine constitutes one of the great philosophical landmarks of the Nineteenth Century.

LESSON 45

THE GLACIAL EPOCH

"To reside
In thrilling region of thick-ribbed ice."
—SHAKESPEARE.

1. The proof of the geologically recent occurrence in the north temperate zone of a glacial epoch, during which large portions of Europe and North America were buried in ice, may, from one point of view, be thought to prove that other agents than those now in operation have acted in past ages, and thus to disprove the main proposition of the uniformitarians.

2. But, on the other hand, its existence has been

demonstrated by those very methods which Sir Charles Lyell advocated—the accurate observation of what nature is doing now—while an ice age really exists at the present time in Greenland, in the same latitude as nearly the whole of Sweden and Norway, which enjoy a comparatively mild climate.

3. The first clear statement of the evidence for a former ice age was given, in 1822, by a Swiss engineer named Venetz. He pointed out that, where the existing glaciers have retreated, the rocks which they had covered are often rounded, smoothed, and polished, or grooved and striated in the direction of the glacier's motion; and that, far away from any existing glaciers, there were to be seen rocks similarly rounded, polished, and striated; while there also existed old moraine heaps exactly similar to those formed at present; and that these phenomena extended as far as the Jura range, on the flanks of which there were numbers of huge blocks of stone, of a kind not found in those mountains, but exactly similar to the ancient rocks of the main alpine chain. Hence, he concluded that glaciers formerly extended down the Rhone valley as far as the Jura, and there deposited those erratic blocks, the presence of which had puzzled all former observers.

4. Soon afterwards, Charpentier and Agassiz devoted themselves to the study of the records left by the ancient glaciers; and from that time to the present a band of energetic workers in every part of the world have, by minute observation and reasoning, established the fact of the extension of glaciers or ice-sheets over a large portion of the north temperate zone; and have also determined the direction of their motion and the thickness of the ice in various parts of their course.

5. These conclusions are now admitted by every geologist who has devoted himself to the subject, and

are embodied in the various official geological surveys of the chief civilised countries; and as they constitute one of the most remarkable chapters in the past history of the globe, and especially as this great change of climate occurred during the period of man's existence

114. A TYPICAL GLACIER
(Roseg, in the Bernina Alps)

on the earth, a brief sketch of the facts must be here given.

6. The complete general similarity of the conclusions reached by four different sets of observers in four different areas—Switzerland, North-Western Europe, the British Isles, and North America—after fifty years

of continuous research, and after every other less startling theory had been put forth and rejected as wholly inconsistent with the phenomena to be explained, renders it as certain as any conclusion from indirect evidence can be, that a large portion of the north temperate zone, now enjoying a favourable climate and occupied by the most civilised nations of the world, was, at a very recent epoch, geologically speaking, completely buried in ice, just as Greenland is now.

7. How recently the ice has passed away is shown by the perfect preservation of innumerable moraines, perched blocks, erratics, and glaciated rock surfaces, showing that but little denudation has occurred to modify the surface; while undoubted relics of man found in glacial or interglacial deposits prove that it occurred during the human period. It is clear that man could not have lived in any area while it was actually covered by the ice-sheet, while any indications of his presence at an earlier period would almost certainly be destroyed by the enormous abrading and grinding power of the ice.

8. Besides the areas above referred to, there are widespread indications of glaciation in parts of the world where a temperate climate now prevails. In the Pyrenees, Caucasus, Lebanon, and Himalayas glacial moraines are found far below the lower limits they now attain.

9. In the Southern Hemisphere similar indications are found in New Zealand, Tasmania, and the southern portion of the Andes; but whether this cold period was coincident with that of the Northern Hemisphere we have at present no means of determining, nor even whether they were coincident among themselves, since it is quite conceivable that they may have been due to local causes, such as greater elevation of the land, and

not to any general cause acting throughout the south temperate zone.

10. In the north temperate zone, however, the phenomena are so widespread and so similar in character, with only such modifications as are readily explained by proximity to, or remoteness from, the ocean, that we are almost sure they must have been simultaneous, and have been due to the same general causes, though perhaps modified by local changes in altitude, and consequent modification of winds or ocean currents.

11. The time that has elapsed since the ice-sheet of the Northern Hemisphere passed away is, geologically, very small indeed, and has been variously estimated at from 20,000 to 100,000 years. At present the smaller period is most favoured by geologists, but the duration of the ice-age itself, including probably one or more inter-glacial mild periods, is admitted to be much longer, and probably to approach the higher figure above given.

12. The undoubted fact, however, that a large part of the north temperate zone has been recently subjected to so marvellous a change of climate, is of immense interest from many points of view. It teaches us, in an impressive way, how delicate is the balance of forces which renders what are now the most densely peopled areas habitable by man.

13. We can hardly suppose that even the tremendously severe ice-age, of which we have evidence, is the utmost that can possibly occur; and, on the other hand, we may anticipate that the condition of things which, in earlier geological times, rendered even the polar regions adapted for a luxuriant woody vegetation, may again recur, and thus vastly extend the area of our globe adapted to support human life in abundance and comfort.

LESSON 46

PROOFS OF GLACIAL ACTION

"Still, with those white-robed Shapes—a living Stream,
The glacier Pillars join in solemn guise:
A product of that awful Mountain scene,
Poured from his vaults of everlasting snow."

—WORDSWORTH.

1. There are four main groups of phenomena which demonstrate the former existence of glaciers in areas where they are now absent: (*a*) Moraines and glacial drifts or gravels; (*b*) smoothed, rounded, or planed rocks; (*c*) striæ, grooves, and furrows on rock-surfaces; (*d*) erratics and perched blocks.

2. Moraines are formed by all existing glaciers, consisting of the earth and rocks which fall upon the ice-rivers from the sides of the valleys through which they flow. The slow motion of the glacier carries these down with it, and they are deposited in great heaps where it melts.

3. In some glaciers, where the tributary valleys are numerous and the *débris* that falls upon the ice is abundant, the whole of the lower part of the glacier for many miles is so buried in it that the surface of the ice cannot be seen, and in these cases there will be a continuous moraine formed across the valley where the glacier terminates.

4. The characteristics of moraines are, that they consist of varied materials, earth, gravel, and rocks of various sizes intermingled confusedly; and they often form mounds or ridges completely across a valley, except where the stream passes through it; while in other cases they extend laterally along the slopes of the hillsides, where, owing to the form of the valley,

the glacier has shrunk in width and left its lateral moraine behind it.

5. In many cases huge blocks of rock rest on the very summit of a moraine, or, in the case of lateral moraines, on the very edge of a precipice in positions where no known agency but ice could have deposited them. These are called "perched blocks."

6. Drifts or glacial gravels are deposits of material similar to that forming the moraines, but spread widely over districts which have formerly been buried in ice. These are often partially formed of stiff clay, in which are embedded quantities of smoothed and striated stones; but the great characteristic of all these ice-products is that the materials are not stratified — that is, sorted according to their fineness or coarseness, as is always the case when deposited by water—but are mingled confusedly together, the large stones being scattered all through the mass, and usually being quite as abundant at the top as at the bottom of the deposit.

115. A PERCHED BLOCK (IN THE PASS OF LLANBERIS)

7. Such deposits are to be found all over the north and north-west of our islands, and are often well exhibited in railway cuttings; and wherever they are fully developed, and the materials of which they con-

sist differ from those forming the underlying rocks, they are an almost infallible indication of the former existence of a glacier or ice-sheet.

8. The smoothed and rounded rocks, called in Switzerland *roches moutonnées,* from their resemblance at a distance to recumbent sheep, are present in almost all recently-glaciated mountainous countries, especially where the rocks are very hard.

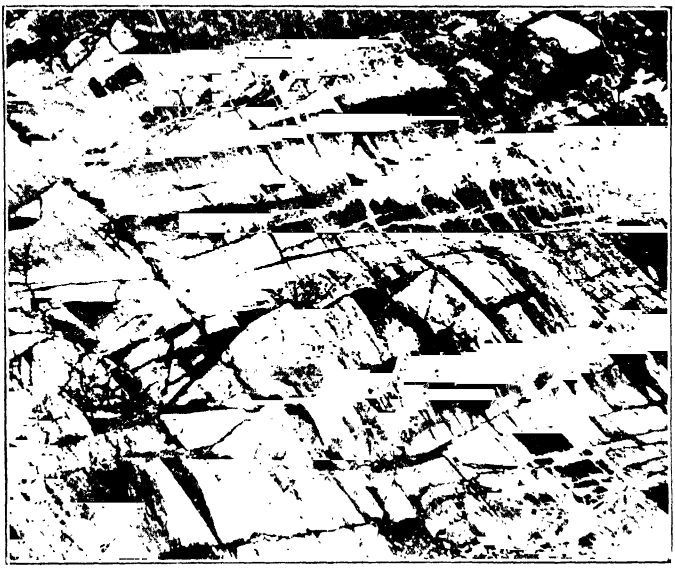
9. They are to be seen in all the higher valleys of Wales, the Lake District, and Scotland, and on examination are found to consist often of the hardest and toughest rocks. In other cases the rock forming the bed of the valley is found to be planed off smooth, even when it consists of hard crystalline strata thrown up at a high angle, and which naturally weathers into a jagged or ridged surface.

116. ROCHES MOUTONNÉES (IN IDAHO, U.S.A.)

10. The smoothed rocks are often found to be covered with numerous striæ, deep grooves, or huge flutings, and these are almost always in one direction, which is that of the course of the glacier. They may often be traced in the same direction for miles, and do not change in harmony with the lesser inequalities of the valley, as they would certainly do had they been formed by water action. These striæ and smoothed rocks are often found hundreds or even thousands of feet above the floor of the valley, and in many cases a

definite line can be traced, above which the rocks are rugged and jagged, while below it they are all more or less rounded, smooth, or polished.

11. Erratic blocks are among the most widespread and remarkable indications of glacial action, and they were the first that attracted the attention of men of science. The great plains of Denmark, Northern Germany, and Russia are strewn with large masses of granite and hard metamorphic rocks, and these rest either on glacial drift or on quite different rocks of Secondary or Tertiary age.



117. ROCK GROOVINGS (NEAR BARMOUTH)

12. The above illustration from a photograph shows a fine example of nearly horizontal groovings, with smooth or polished surfaces, in the older Cambrian rocks of North Wales.

LESSON 47

ERRATICS

"The rocks drawn down
From yon remotest waste, have overthrown
"The limits of the dead and living world."—SHELLEY.

1. The most interesting and instructive erratic blocks are those found upon the slopes of the Jura, because they have been most carefully studied by Swiss and French geologists, and have all been traced to their sources in the Alpine chain.

2. The Jura mountains consist wholly of secondary limestones, and are situated opposite to the Bernese Alps, at a distance of about fifty miles. Along their slopes for a distance of a hundred miles, and extending from their base to a height of 2000 feet above the Lake of Neuchâtel, are great numbers of rocks, some of them as large as houses, and always quite different from that of which the Jura range is formed.

3. These have all been traced to their parent rocks in various parts of the course of the old glacier of the Rhone, and, what is even more remarkable, their distribution is such as to prove that they were conveyed by a glacier, and not by floating ice during a period of submergence.

4. The rocks and other *débris* that fall upon a glacier from the two sides of its main valley form distinct moraines upon its surface, and however far the glacier may flow, and however much it may spread out where the valley widens, they preserve their relative position; so that whenever they are deposited by the melting of the glacier, those that came from the north side of the valley will remain completely separated from those which came from the south side.

It was this fact which convinced Sir Charles Lyell that the theory of floating ice, which he had first adopted, would not explain the distribution of the erratics, and he has given in his "Antiquity of Man" (4th ed., p. 344) a map showing the course of the blocks as they were conveyed on the surface of the glacier to their several destinations.

5. Other blocks are found on the lower slopes of the Alpine chain towards Bern on one side and Geneva on the other, while the French geologists have traced them down the Rhone valley seventy miles from Geneva, and also more than twenty miles west of the Jura, thus proving that at the lowest portion of that chain the glacier flowed completely over it. In all these cases the blocks can be traced to a source corresponding to their position on the theory of glacier action. Some of these rocks have been carried considerably more than two hundred miles, proving that the old glacier of the Rhone extended to this enormous distance from its source.

118. AN "ERRATIC"
(A Silurian Erratic upon limestone. Mount Ingleborough, Yorkshire)

6. In our own islands and in North America, these various classes of evidence have been carefully studied, the direction of the glacial striæ everywhere ascer-

tained, and all the more remarkable erratic blocks traced to their sources, with the result that the extent and thickness of the various glaciers and ice-sheets are well determined, and the direction of motion of the ice ascertained. The conclusions arrived at are very extraordinary, and must be briefly indicated.

7. In Great Britain, during the earlier and later phases of the ice-age, all the mountains of Scotland, the Lake District, and Wales produced their own glaciers, which flowed down to the sea.

8. But at the time of the culmination of the Glacial Epoch the Scandinavian ice-sheet extended on the south-east till it filled up the Baltic Sea and spread over the plains of North-Western Europe, and also filled up the North Sea, joining the glaciers of Scotland, forming with them a continuous ice-sheet from which the highest mountains alone protruded. It also reached the coast of Yorkshire and piled up great beds of boulder clay, containing numbers of broken or striated rocks formed of material whose peculiar structure proves them to be of Scandinavian origin. The coloured plate which forms the frontispiece of this book shows a great bed of this glacial deposit upon the chalk cliffs near Flamborough Head.

9. At the same time this Scotch ice-sheet extended into the Irish Sea, and united with the glaciers of the Lake District, Wales, and Ireland, till almost continuous ice-sheets enveloped those countries also. Glacial striæ are found up to a height of 3500 feet in Scotland, and 2500 feet in the Lake District and in Ireland; while the Isle of Man was completely overflowed, as shown by glacial striæ on the summit of its loftiest mountains.

10. Erratics from Scandinavia are found in great quantities on Flamborough Head, mixed with others

from the Lake District and Galloway, showing that two ice-streams met here from opposite directions. Erratics from Scotland are also found in the Lake District, in North Wales, in the Isle of Man, and in Ireland, from which the direction of the moving ice can be determined.

11. Great numbers of local rocks have also been carried into places far from their origin, and in every case this displacement is in the direction of the flow of the ice as ascertained by the other evidence—never in the opposite direction.

12. Each great mountain area had, however, its own centre of local dispersal, depending upon the position of greatest thickness of the ice-sheet, which was not necessarily that of the highest mountains, but was approximately the centre of the main area of glaciation. Thus the centre of the North Wales ice-sheet was not at Snowdon, but over the Arenig mountains, which thus became a local centre of dispersal of erratics.

13. In Ireland, the mountains being placed around the coasts, the great central plain became filled with ice, which, continually accumulating, formed a huge dome of ice whose outward pressure caused motion in all directions till checked by the opposing motion of the great Scandinavian ice-sheet. This strange fact has been demonstrated by the work of the Irish Geological Survey and by many local geologists, and is universally accepted by all who have studied the evidence.

14. When we cross the Atlantic the phenomena are equally remarkable. The whole of the north-eastern United States and Canada were also buried in an ice-sheet of enormous thickness and extent. It came southward as far as New York, and inland,

in an irregular line by Cincinnati to St. Louis on the Mississippi. The whole of the region to the north of this line is covered with a deposit of drift, often of enormous thickness, while, embedded in the drift or scattered over its surface, are numbers of blocks and rock-masses, often formed of materials quite foreign to the bed-rock of the district.

15. These erratics have in many cases been traced to their sources, sometimes six hundred miles away, and the study of these, and of the numerous grooved and striated rocks, show that the centre of dispersal was far north of the Alleghanies and its outliers, and, as in the case of Ireland, must have consisted of a huge dome of ice situated over the plateau to the north of the great lakes, in what must have been an area of great snowfall combined with a very low temperature. The maximum thickness of this great ice-sheet must have been at least a mile over a considerable portion of its area, as glacial deposits have been found on the summit of Mount Washington at an altitude of nearly 6000 feet, and the centre of motion was a considerable distance to the north-west, where it much have reached a still greater altitude.

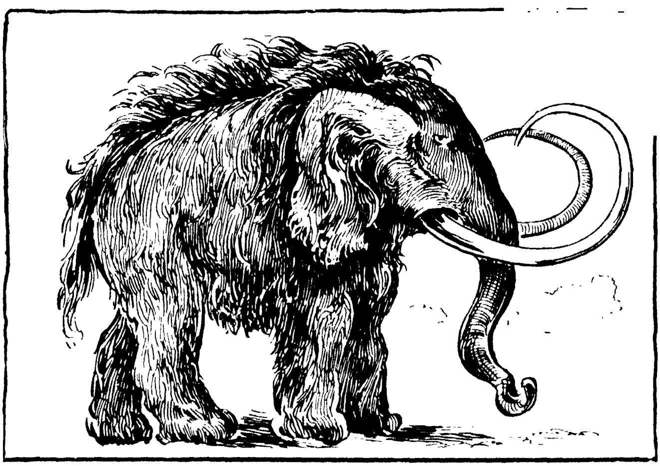
16. These various facts, founded upon minute and long-continued observations by the chief geologists of Europe and North America, serve to complete the demonstration of the recent occurrence of the Great Ice Age, a discovery which, if not of the very first rank, is yet of sufficient importance to take its place among the great scientific achievements of the past century.

LESSON 48

THE ANTIQUITY OF MAN

"With cunning hand he shapes the flint,
He carves the bone with strange device,
He splits the rebel rock by dint
Of effort—till one day there flies
A spark of fire from out the stone,
Fire, which shall make the world his own."
—MATHILDE BLIND.

1. Following the general acceptance of a glacial epoch by about twenty years, but to some extent con-



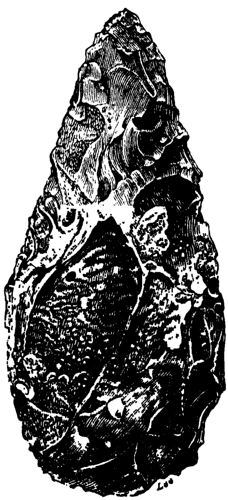
119. THE MAMMOTH

nected with it, came the recognition that man had existed in Northern Europe along with numerous animals which no longer live there—the mammoth,

the woolly rhinoceros, the wild horse, the cave-bear, the lion, the sabre-toothed tiger, and many others —and that he had left behind him, in an abundance of rude flint implements, the record of his presence.

2. Before that time geologists, as well as the whole educated world, had accepted the dogma that man only appeared upon the earth when both its physical features and its animal and vegetable forms were exactly as we find them to-day; and this belief, resting solely on negative evidence, was so strongly and irrationally maintained, that the earlier discoveries could not get a hearing.

3. A careful but enthusiastic French observer, M. Boucher de Perthes, had for many years collected with his own hands, from the great deposits of old river gravels in the valley of the Somme near Amiens, abundance of large and well-formed flint implements. In 1847, he published an account of them, but nobody believed his statements till, ten years later, Dr. Falconer, and, shortly afterwards, Professor Prestwich and Mr. John Evans, examined the collections and the places where they were found, and were at once convinced of their importance; and their testimony led to the general acceptance of the doctrine of the great antiquity of the human race. From that



120. PALÆOLITHIC FLINT IMPLEMENT, AMIENS
(From Lyell's *Elements of Geology*; by permission of Mr. John Murray)

time researches on this subject have been carried on by many earnest students, and have opened up a number of altogether new chapters in human history.

4. So soon as the main facts were established, many old records of similar discoveries were called to mind, all of which had been ignored or explained away on account of the strong prepossession in favour of the very recent origin of man.

5. In 1715, flint weapons had been found in excavations near Gray's Inn Lane, along with the skeleton of an elephant. In 1800, another discovery was made in Suffolk of flint weapons and the remains of extinct animals in the same deposits. In 1825, Mr. McEnery, of Torquay, discovered worked flints along with the bones and teeth of extinct animals in Kent's Cavern. In 1840, a good geologist confirmed these discoveries, and sent an account of them to the Geological Society of London, but the paper was rejected as being too improbable for publication!

6. All these discoveries were laughed at or explained away, as the glacial striæ and grooves so beautifully exhibited in the Vale of Llanberis were at first endeavoured to be explained as the wheel-ruts caused by the chariots of the ancient Britons! These, combined with numerous other cases of the denial of facts on *à priori* grounds, have led me to the conclusion that, whenever the scientific men of any age disbelieve other men's careful observations without inquiry, the scientific men are *always* wrong.

7. Even after these evidences of man's great antiquity were admitted, strenuous efforts were made to minimise the time as measured by years; and it was maintained that man, although undoubtedly old, was entirely post-glacial. But evidence has been steadily accumulating of his existence at the time of the glacial

epoch, and even before it; while two discoveries of recent date seem to carry back his age far into pre-glacial times.

8. These are, first, the human cranium, bones, and works of art which have been found more than a hundred feet deep in the gold-bearing gravels of California, associated with abundant vegetable remains of extinct species, and overlaid by four successive lava streams from long extinct volcanoes. The other case is that of rude stone implements discovered by a geologist of the Indian Survey in Burma in deposits which are admitted to be of at least Pliocene Age.

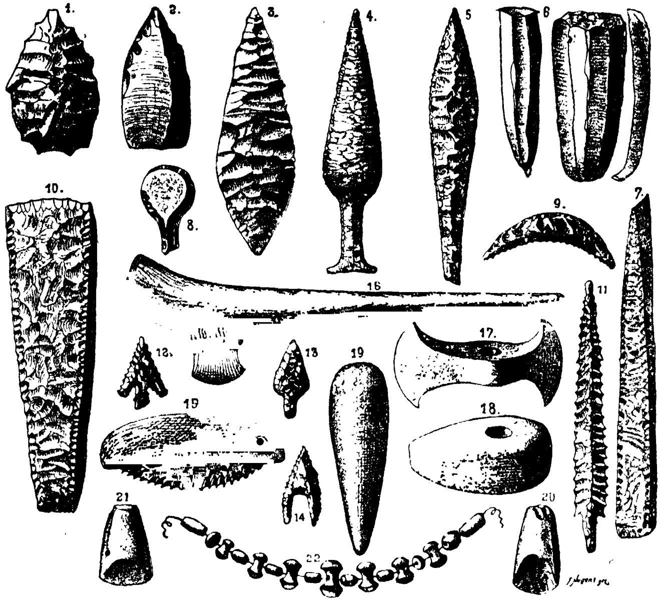
9. In both these cases the evidence is disputed by a few geologists, who seem to think that there is something unscientific, or even wrong, in admitting evidence that would prove the Pliocene age of any other animal to be equally valid in the case of man. There is assumed to be a great improbability of his existence earlier than the very end of the Tertiary epoch.

10. But all the indications drawn from his relations to the anthropoid apes point to an origin far back in Tertiary time. For each one of the great apes—the gorilla, the chimpanzee, the orang, and even the gibbons—resemble man in certain features more than do their allies, while in other points they are less like him.

11. Now, if man has been developed from a lower animal form, we must seek his ancestors not in the direct line between him and any of these apes, but in a line towards a common ancestor to them all; and this common ancestor must certainly date back to the early part of the Tertiary epoch, because in the Miocene period anthropoid apes not very different from living forms have been found fossil.

12. There is, therefore, no improbability whatever

in the existence of man in the later portions of the Tertiary period, and we have no right, scientifically, to treat any evidence for his existence in any other way than the evidence for the existence of other animal types.



121. NEOLITHIC STONE IMPLEMENTS AND WEAPONS

13. But besides these older and ruder stone implements used by the men who were contemporaries of the mammoth in Britain, stone weapons and implements of a more elaborate type are found, some beautifully and regularly chipped, others ground smooth, and of shapes which at a still later period were copied in bronze or iron (fig. 121). These are said to be of the Neolithic, or newer Stone Age, and a great lapse of time separates them from the older type. The men

of the Neolithic age were contemporaries of animals and plants now living. They practised agriculture, and had several of our domestic animals, and were the direct ancestors of races now inhabiting Europe.

14. The certainty that man coexisted with many now extinct animals, and the probability of our discovering his remains in undoubted Tertiary strata, constitutes an immense advance on the knowledge and beliefs of our forefathers, and must therefore rank among the prominent features in the scientific progress of the Nineteenth Century.

LESSON 49

EVOLUTION AND NATURAL SELECTION

"Enkindled in the mystic dark,
Life built herself a myriad forms,
And, flashing its electric spark
Through films, and cells, and pulps, and worms,
Flew shuttlewise above, beneath,
Weaving the web of life and death."
—MATHILDE BLIND.

1. We now approach the subject which, in popular estimation, and perhaps in real importance, may be held to be the great scientific work of the Nineteenth Century—the establishment of the general theory of evolution, by means of the special theory of the development of the organic world through the struggle for existence and its necessary outcome, Natural Selection.

2. Although in the eighteenth century Buffon, Dr. Erasmus Darwin, and the German poet Goethe, had put forth various hints and suggestions pointing to evolution in the organic world, which they undoubtedly believed to have occurred, no definite statement of the theory

had appeared till early in the nineteenth century, when La Place explained his views as to the evolution of the stellar universe and of solar and planetary systems in his celebrated Nebular Hypothesis; and about the same time Lamarck published his "Philosophie Zoologique," containing an elaborate exposition of his theory of the progressive development of animals and plants. But this theory gained few converts among naturalists, partly because Lamarck was before his time, and also because the causes he alleged did not seem adequate to produce the wonderful adaptations we everywhere see in nature.

3. During the first half of the nineteenth century, owing to the fact that Brazil, South Africa, and Australia then became for the first time accessible to English collectors, the treasures of the whole world of nature were poured in upon us so rapidly, that the comparatively limited number of naturalists were fully occupied in describing the new species and endeavouring to discover true methods of classification.

4. The need of any general theory of how species came into existence was hardly felt; and there was a general impression that the problem was at that time insoluble, and that we must spend at least another century in collecting, describing, and classifying, before we had any chance of dealing successfully with the origin of species. But the subject of evolution was ever present to the more philosophic thinkers, though the great majority of naturalists and men of science held firmly to the dogma that each species of animal and plant was a distinct creation, though how produced was admitted to be both totally unknown and almost, if not quite, unimaginable.

5. The vague ideas of those who favoured evolution were first set forth in systematic form, with much

literary skill and scientific knowledge, by the late Robert Chambers in 1844, in his anonymous volume, "Vestiges of the Natural History of Creation." He passed in review the stellar and solar systems, adopted the nebular hypothesis, and sketched out the geological history of the earth, with continuous progression from lower to higher forms of life.

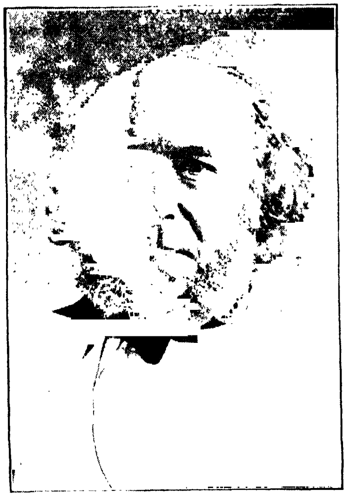
6. After describing the peculiarities of the lower plants and animals, dwelling upon those features which seemed to point to a natural mode of production as opposed to an origin by special creation, the author set forth with much caution the doctrine of progressive development resulting from "an impulse which was imparted to the forms of life, advancing them in definite lines, by generation, through grades of organisation terminating in the highest plants and animals." The reasonableness of this view was urged through the rest of the work; and it was shown how much better it agreed with the various facts of nature and with the geographical distribution of animals and plants, than the idea of the special creation of each distinct species.

122. ROBERT CHAMBERS

7. It will be seen, from this brief outline of the book, that there was no attempt whatever to show *how* or *why* the various species of animals and plants acquired their peculiar characters, but merely an argument in favour of the reasonableness of the fact

of progressive development, from one species to another, through the ordinary processes of generation.

8. The book was what we should now call mild in the extreme. It was serious and even religious in tone, and calculated in this respect to disarm the opposition even of the most orthodox theologists; yet it was met with just the same storm of opposition and indignant abuse which assailed Darwin's work fifteen years later.


123. HERBERT SPENCER

9. I well remember the excitement caused by the publication of the "Vestiges," and the eagerness and delight with which I read it. Although I saw that it really offered no explanation of the process of change of species, yet the view that the change was effected, not through any unimaginable process, but through the known laws and processes of reproduction, commended itself to me as perfectly satisfactory, and as affording the first step towards a more complete and explanatory theory. It seems now a most amazing thing that even to argue for this first step was accounted a heresy, and was almost universally condemned as being opposed to the teachings of both science and religion!

10. The book was, however, as great a success as, later on, was Darwin's "Origin of Species." Four editions were issued in the first seven months, and by 1860

it had reached the eleventh edition, and about 24,000 copies had been sold. It is certain that this work did great service in familiarising the reading public with the idea of evolution, and thus preparing them for the more complete and efficient theory laid before them by Darwin.

11. During the fifteen years succeeding the publication of the "Vestiges," many naturalists expressed their belief in the progressive development of organic forms; while, in 1852, Herbert Spencer published his essay contrasting the theories of Creation and Development with such skill and logical power as to carry conviction to the minds of all unprejudiced readers; but none of these writers suggested any definite theory of *how* the change of species actually occurred. That was first done in 1858; and, in connection with it, I may, perhaps, venture to give a few personal details.

LESSON 50

THE SURVIVAL OF THE FITTEST

"The world moves on in singing harmony—
Her steps of eon length: from primal cloud,
First through her realms old Chaos calls aloud;
Then, splashing in the Mesozoic sea,
Huge heralds of the beauty yet to be,
Her saurian monsters rise; they pass away,
And lo! the glories of a better day,
And man, the God-within, not fully free."

—*American Fabian.*

1. Ever since I read the "Vestiges," I had been convinced that development took place by means of the ordinary process of reproduction; but though this was widely admitted, no one had set forth the various kinds of evidence that rendered it almost a certainty.

I endeavoured to do this in an article written at Sarawak in February 1855, which was published in the following September in the *Annals of Natural History.*

2. Relying mainly on the well-known facts of geographical distribution and geological succession, I deduced from them the law, or generalisation, that, "Every species has come into existence coincident both in space and time with a pre-existing closely allied species;" and I showed how many peculiarities in the affinities, the succession, and the distribution of the forms of life, were explained by this hypothesis, and that no important facts contradicted it.

3. Even then, however, I had no conception of *how* or *why* each new form had come into existence with all its beautiful adaptations to its special mode of life; and though the subject was continually being pondered over, no light came to me till three years later (February 1858), under somewhat peculiar circumstances. I was then living at Ternate in the Moluccas, and was suffering from a rather severe attack of intermittent fever, which prostrated me for several hours every day during the cold and succeeding hot fits.

4. During one of these fits, while again considering the problem of the origin of species, something led me to think of Malthus' "Essay on Population" (which I had read about ten years before), and the "positive checks"—war, disease, famine, accidents, &c.—which he adduced as keeping all savage populations nearly stationary. It then occurred to me that these checks must also act upon animals, and keep down their numbers; and as they increase so much faster than man does while their numbers are always very nearly or quite stationary, it was clear that these checks in their case must be far more powerful, since a number

equal to the whole increase must be cut off by them every year.

5. While vaguely thinking how this would affect

124. DARWIN

(*From a Photograph by Captain Darwin, R.E.*

any species, there suddenly flashed upon me the idea of *the survival of the fittest*—that the individuals removed by these checks must be, on the whole, *inferior*

to those that survived. Then, considering the *variations* continually occurring in every fresh generation of animals or plants, and the changes of climate, of food, of enemies always in progress, the whole method of specific modification became clear to me, and in the two hours of my fit I had thought out the main points of the theory.

6. That same evening I sketched out the draft of a paper; in the two succeeding evenings I wrote it out, and sent it by the next post to Mr. Darwin.[1] I fully expected it would be as new to him as it was to myself, because he had informed me by letter that he was engaged on a work intended to show in what way species and varieties differ from each other, adding, "my work will not fix or settle anything."

7. I was therefore surprised to find that he had really arrived long before (in 1844) at the very same theory as mine, had worked it out in considerable detail, and had shown the MS. to Sir Charles Lyell and Sir Joseph Hooker; and on their recommendation my paper and sufficient extracts from his MS. work were read at a meeting of the Linnean Society in July of the same year, when the theory of Natural Selection or survival of the fittest was first made known to the world. But it received little attention till Darwin's great and epoch-making book appeared at the end of the following year.

8. We may best attain to some estimate of the greatness and completeness of Darwin's work by considering the vast change in educated public opinion which it rapidly and permanently effected. What that opinion was before it appeared is shown by the fact that neither Lamarck, nor Herbert Spencer, nor the

[1] These two papers are reprinted in my "Natural Selection and Tropical Nature."

author of the "Vestiges," had been able to make any impression upon it.

9. The very idea of progressive development of species from other species was held to be a "heresy" by such great and liberal-minded men as Sir John Herschel and Sir Charles Lyell, the latter writer declaring, in the earlier editions of his great work, that the facts of geology were "fatal to the theory of progressive development." The whole literary and scientific worlds were violently opposed to all such theories, and altogether disbelieved in the possibility of establishing them. It had been so long the custom to treat species as special creations, and the mode of their creation as "the mystery of mysteries," that it had come to be considered not only presumptuous, but almost impious, for any individual to profess to have lifted the veil from what was held to be the greatest and most mysterious of Nature's secrets.

10. But what is the state of educated literary and scientific opinion at the present day? Evolution is now universally accepted as a demonstrated principle, and not one single writer of the slightest eminence, that I am aware of, now declares his disbelief in it.

11. This is, of course, partly due to the colossal work of Herbert Spencer; but for one reader of his works there are probably ten of Darwin's, and the establishment of the theory of the "Origin of Species by means of Natural Selection" is wholly Darwin's work. That book, together with those which succeeded it, has so firmly established the doctrine of progressive development of species by the ordinary processes of multiplication and variation, that there is now, I believe, scarcely a single living naturalist who doubts it.

12. Probably so complete a change of educated opinion on a question of such vast difficulty and

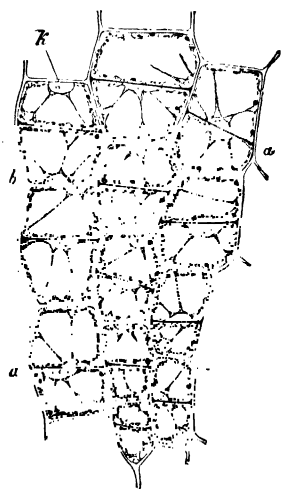
complexity was never before effected in so short a time. It not only places the name of Darwin on a level with that of Newton, but his work will always be considered as one of the greatest, if not the very greatest, of the scientific achievements of the nineteenth century, rich as that century has been in great discoveries in every department of physical science.

LESSON 51

POPULAR DISCOVERIES IN PHYSIOLOGY

"Recluse, th' interior sap and vapour dwells,
In nice transparence of minutest cells."
—H. Brooke.

1. The science of Physiology, which investigates the complex phenomena of the motions, sensations, growth and development of organisms, is almost wholly the product of the nineteenth century; but with the exception of a few fundamental conceptions, it has been an almost continuous growth by small increments, and offers few salient points of popular interest, or which can be made intelligible to the general reader.



125. CELLS IN STEM OF BEAN
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2. The first of the great fundamental conceptions referred to is the cell-theory, which was definitely established for plants in 1838, and immediately afterwards for animal structures.

3. The theory is, that all the parts and tissues of plants and animals are built up of cells, modified in form and function in an infinite variety of ways, but to be traced in the early stages of growth, alike of bone and muscle, nerve and blood-vessel, skin and hair, root, wood, and flower. And, further, that all organisms originate in simple cells, which are almost identical in form and structure, and which thus constitute the fundamental unit of all living things.

4. The second great generalisation is what has been termed the recapitulation theory of development. Every animal or plant begins its existence as a cell, which develops by a process of repeated division and growth into the perfect form. But if we trace the different types backward, we find that we come to a stage when the embryos of all the members of an order, such as the various species of Ruminants, are undistinguishable; earlier still all the members of a class, such as the Mammalia, are equally alike, so that the embryos of a sheep and a tiger would be almost identical; earlier still all vertebrates—a lizard, a bird, and a monkey—are equally undistinguishable.

5. Thus in its progress from the cell to the perfect form every animal recapitulates, as it were, the lower forms upon its line of descent, thus affording one of the strongest indirect proofs of the theory of evolution. The earliest definite result of cell-division is to form what is termed the "gastrula," which is a sac with a narrow mouth, formed of two layers of cells. All the higher animals without exception, from mollusc to man, go through this "gastrula" stage, which again indicates that all are descended from a common ancestral form of this general type.

6. One other physiological discovery is worth noting here, both on account of its remarkable nature and

because it leads to some important conclusions in relation to the zymotic diseases.

7. Quite recently it has been proved that the white corpuscles of the blood, whose function was previously unknown, are really independent living organisms. They are produced in large numbers by the spleen, an organ which has long been a puzzle to physiologists, but whose function and importance to the organism seem to be now made clear. They are much smaller and less numerous than the red blood-globules; they move about quite independently; and they behave in a manner which shows that they are closely allied to, if not identical with, the amœbæ found abundantly in stagnant water, and which form such interesting microscopic objects.

8. These minute animal organisms, which inhabit not only our blood-vessels but all the tissues of the body, have an important function to perform on which our very lives depend. This function is, to devour and destroy the bacteria or germs of disease which may gain an entrance to our blood or tissues, and which, when their increase is unchecked, produce various disorders and even death.

9. Under the higher powers of the microscope the leucocytes, as they are termed, can be observed continually moving about, and on coming in contact with any of these bacteria or their germs, or other hurtful substances, they send out pseudo-podia, or foot-like processes, from their protoplasm which envelops the germ and soon causes it to disappear; but they also appear sometimes to produce a secretion which is injurious to the bacteria, and so destroys them, and these may perhaps be distinct organisms.

10. It seems probable, and, in fact, almost certain,

that so long as we live in tolerably healthy conditions, these leucocytes (or phagocytes as they are sometimes called from their function of devouring injurious germs) are able to deal with all disease-germs which can gain access to our system; but when we live in impure air, or drink impure water, or feed upon unwholesome food, our system becomes enfeebled, and our guardian leucocytes are unable to destroy the disease-germs that gain access to our organism; they then increase rapidly, and are the cause of disease and death.

11. We learn from this marvellous discovery that, so long as we live simply and naturally, and obey the well-known laws of sanitation, so as to secure a healthy condition of the body, the much-dreaded zymotic diseases will be powerless against us. But if we neglect these laws of health, or allow of conditions which compel large bodies of our fellow-men to neglect them, these disease-germs will be present in such quantities in the air and the water around us, that even those who personally live comparatively wholesome lives will not always escape them.

12. We learn, too, another lesson from this latest discovery of the secrets of the living universe. Just as we saw how, physically, dust was so important that not only much of the beauty of nature but the very habitability of our globe depended upon it, so we now find that the most minute and most abundant of all organisms are those on which both our means of life and our preservation from death are dependent.

13. For these minute bacteria of various kinds are present everywhere—in the air, in the water, in the soil under our feet. Their function appears to be to break up by putrefactive processes all dead organised matter, and thus prepare it for being again assimilated by plants, so as to form food for animals and for man;

and it seems probable that they prepare the soil itself for plant-growth by absorbing and fixing the nitrogen of the atmosphere. They are, in fact, omnipresent, and under normal conditions they are wholly beneficial. It is we ourselves who, by our crowded cities, our polluted streams, and our unnatural and unwholesome lives, enable them to exert their disease-creating powers.

LESSON 52

ANÆSTHETICS AND ANTISEPTICS

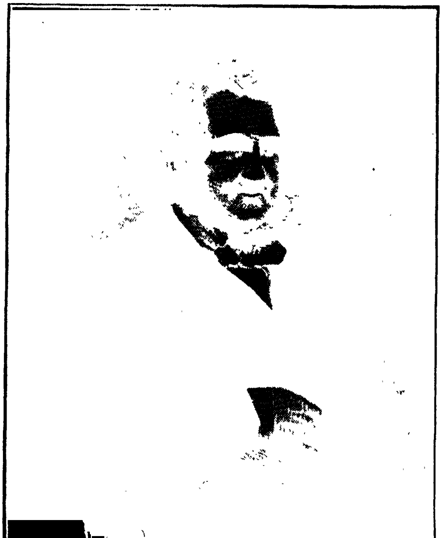
"But a heavenly sleep
That did suddenly steep
In balm my bosom's pain."
—SHELLEY.

1. A brief notice must now be given of two discoveries in practical physiology, which have perhaps done more to benefit mankind that those great mechanical inventions and philosophical theories which receive more general admiration. These are, the use of anæsthetics in surgical operations, and the antiseptic treatment of wounds.

2. Anæsthetics were first used in dentistry in 1846, the agent being ether; while the use of chloroform, for more severe surgical operations, was introduced by Sir James Simpson in 1848; and though their primary effect is only to abolish pain, they get rid of so much nervous irritation as greatly to aid in the subsequent recovery.

3. The use of anæsthetics thus renders it possible for many operations to be safely performed which, without it, would endanger life by mere shock to the system; while to the operating surgeon it gives con-

fidence, and enables him to work more deliberately and carefully from the knowledge that the longer time occupied will not increase the suffering of the patient or render his recovery less probable. Nitrous-oxide gas is now chiefly used in dentistry or very short operations, sulphuric ether for those of moderate length, while chloroform is usually employed in all the more severe cases, since the patient can by its use be kept in a state of insensibility for an hour or even longer. There is, however, some danger in its use to persons with weak heart or of great nervous sensibility, and the patient in such cases may die from the effects of the anæsthetic alone.



126. SIR JAMES SIMPSON
(The Discoverer of the use of Chloroform in Surgical Operations)

4. Even more important was the introduction of the antiseptic treatment in 1865, which, by preventing the suppuration of incised or wounded surfaces, has reduced the death-rate for serious amputations from forty-five per cent. to twelve per cent., and has besides rendered possible numbers of operations which would have been certainly fatal under the old system. I remember my astonishment

when, soon after the introduction of the practice, I

127. A FIELD HOSPITAL AT WORK

was told by an eminent physiologist of the new method

of performing operations, in which the freshly cut surfaces could be left exposed to the air without dressings of any kind, and would soon heal.

5. The antiseptic treatment was the logical outcome of the proof, that suppuration of wounds and all processes of fermentation and putrefaction were not due to normal changes either in living or dead tissues, but were produced by the growth and the rapid multiplication of minute organisms, especially of those low fungoid groups termed Bacteria.

6. In the pure air of the desert or of lofty mountains, dead animal matter will not putrefy but will simply dry up, and the same is the case if meat is preserved in a cool deep cave or cellar, or near the bottom of a well. Many years ago I heard a farmer in Bedfordshire describe how he had kept a leg of mutton of a very fine breed of sheep in a perfectly dry, cool cellar for six months, at the end of which it was roasted for a dinner party, and all the guests declared they had never eaten such delicious mutton. The same fact was illustrated by Professor Tyndall when he found that animal and vegetable infusions which would putrefy and become full of microscopic organisms when exposed to the air at low altitudes, could be kept for days in the High Alps without undergoing the slightest change. They remained as clear and inodorous as when first made.

7. If, therefore, we can adopt measures to keep away or destroy these organisms and their germs, or in any way prevent their increase, injured living tissues will rapidly heal, while dead animal matter can be preserved unchanged almost indefinitely. In the case of wounds and surgical operations, this is effected by means of a weak solution of corrosive-sublimate, in which all instruments and everything

that comes in contact with the wound are washed, and by filling the air around the part operated on with a copious spray of carbolic acid.

8. Cold has a similar effect in preserving meat; while the process of tinning various kinds of food depends for its success on the same principle, of first killing all bacteria or other germs by heating the filled tins above the boiling-point, and then keeping out fresh germs by an air-tight fastening.

9. The combined use of anæsthetics and antiseptics has almost robbed the surgeon's knife of its terrors, and has enabled the most deeply-seated organs to be laid open and operated upon with success. As a result, more lives are probably now saved by surgery than by any other branch of medicine, since in the treatment of disease there has been comparatively small progress except by trusting more to the healing powers of nature, aided by rest, warmth, pure air, wholesome food, and as few drugs as possible.

LESSON 53

ESTIMATE OF ACHIEVEMENTS

"The long crude efforts of society
    In feeble light by feeble reason led,—
But gleaning, gathering still, effect of cause,
    Cause of effect, in ceaseless sequence fed;
Till, slow developing the eons through,
    The gibbering savage to a Darwin grew—
This hath Time witnessed! Shall his records now,
The goal attain'd—the end achieved, avow?"

—J. H. Dell.

1. Having now completed our sketch of those practical discoveries and striking generalisations of science, which have in so many respects changed the

outward forms of our civilisation, and will ever render memorable the past century, we are in a position to sum up its achievements, and compare them with what has gone before.

2. Taking first those inventions and practical applications of science which are perfectly new departures, and which have also so rapidly developed as to have profoundly affected many of our habits, and even our thoughts and our language, we find them to be thirteen in number:—

(1) Railways, which have revolutionised land-travel and the distribution of commodities.

(2) Steam navigation, which has done the same thing for ocean-travel, and has besides led to the entire reconstruction of the navies of the world.

(3) Electric Telegraphs, which have produced an even greater revolution in the communication of thought.

(4) The Telephone, which transmits, or rather reproduces, the voice of the speaker at a distance.

(5) Friction Matches, which have revolutionised the modes of obtaining fire.

(6) Gas-lighting, which enormously improved outdoor and other illumination.

(7) Electric-lighting, another advance, now threatening to supersede gas.

(8) Photography, an art which is to the external forms of nature what printing is to thought.

(9) The Phonograph, which preserves and reproduces sounds as photography preserves and reproduces forms.

(10) The Röntgen Rays, which render many opaque objects transparent, and open up a new world to photography.

(11) Spectrum-analysis, which so greatly extends

our knowledge of the universe, that by its assistance we are able to ascertain the relative heat and chemical constitution of the stars, and ascertain the existence, and measure the rate of motion, of stellar bodies which are entirely invisible.

(12) The use of Anæsthetics, rendering the most severe surgical operations painless.

(13) The use of Antiseptics in surgical operations, which has still further extended the means of saving life.

3. Now, if we ask what inventions comparable with these were made during the eighteenth century, it seems at first doubtful whether there were any. But we may perhaps admit the development of the steam-engine from the rude but still useful machine of Newcomen, to the powerful and economical engines of Boulton and Watt.

4. The principle, however, was known long before, and had been practically applied in the previous century by the Marquis of Worcester and by Savery; and the improvements made by Watt, though very important, had but a limited result. The engines made were almost wholly used in pumping the water out of deep mines, and the bulk of the population knew no more of them, nor derived any more direct benefit from them, than if they had not existed.

5. In the seventeenth century, the one great and far-reaching invention was that of the Telescope, which, in its immediate results of extending our knowledge of the universe and giving possibilities of future knowledge not yet exhausted, may rank with spectrum-analysis in our own era. The Barometer and Thermometer are minor discoveries.

6. In the sixteenth century, we have no invention of the first rank, but in the fifteenth we have printing.

7. The Mariner's Compass was invented early in the fourteenth century, and was of great importance in rendering ocean navigation possible and thus facilitating the discovery of America.

8. Then, backward to the dawn of history, or rather to prehistoric times, we have the two great engines of knowledge and discovery—the Indian or Arabic numerals, leading to arithmetic and algebra, and, more remote still, the invention of alphabetical writing; and the use of fire, the greatest in its results of all material discoveries.

9. Summing these up, we find only five inventions of the first rank in all preceding time—(1) the telescope; (2) the printing-press; (3) the mariner's compass; (4) Arabic numerals; (5) alphabetical writing; (6) fire, to which we may add (7) the steam-engine and (8) the barometer, making eight in all, as against thirteen in our single century.

LESSON 54

THEORETICAL DISCOVERIES

> "How charming is divine philosophy!
> Not harsh and crabbed, as dull fools suppose,
> But musical as is Apollo's lute."—MILTON.

1. Coming now to the theoretical discoveries of our time, which have extended our knowledge or widened our conceptions of the universe, we find them to be about equal in number, as follows:—

(1) The determination of the mechanical equivalent of heat, leading to the great principle of the Conservation of Energy.

(2) The Molecular theory of gases.

(3) The mode of direct measurement of the Velocity

of Light, and the experimental proof of the Earth's Rotation. These are put together, because hardly sufficient alone.

(4) The discovery of the function of Dust in nature.

(5) The theory of definite and multiple proportions in Chemistry.

(6) The nature of Meteors and Comets, leading to the Meteoritic theory of the Universe.

(7) The proof of the Glacial Epoch, its vast extent, and its effects upon the earth's surface.

(8) The proof of the great Antiquity of Man.

(9) The establishment of the theory of Organic Evolution.

(10) The Cell theory and the Recapitulation theory in Embryology.

(11) The Germ theory of the Zymotic diseases.

(12) The discovery of the nature and function of the White Blood-corpuscles.

2. Turning to the past, in the eighteenth century we may perhaps claim two groups of discoveries:—

(1) The foundation of modern Chemistry by Black, Cavendish, Priestley, and Lavoisier; and

(2) The foundation of Electrical science by Franklin, Galvani, and Volta.

3. The seventeenth century is richer in epoch-making discoveries, since we have:—

(1) The theory of Gravitation established.

(2) The discovery of Kepler's Laws.

(3) The invention of Fluxions and the Differential Calculus.

(4) Harvey's proof of the circulation of the Blood.

(5) Roemer's proof of finite velocity of Light by the observation of Jupiter's satellites.

4. Then, going backward, we can find nothing of the first rank except Euclid's wonderful system of Geo-

metry, derived from earlier Greek and Egyptian sources, and perhaps the most remarkable mental product of the earliest civilisations; to which we may add the introduction of Arabic numerals, and the use of the Alphabet, which we have already counted among the practical discoveries. Thus in all past history we find only six theories or principles antecedent to the nineteenth century as compared with twelve during that century.

LESSON 55

COMPARATIVE VIEW OF THE GREAT INVENTIONS AND DISCOVERIES OF THE TWO ERAS

"What a piece of work is man! How noble in reason! How infinite in faculty! In form and moving how express and admirable! In action how like an angel! In apprehension how like a god!"—SHAKESPEARE.

1. It will be well now to give a comparative view of the great inventions and discoveries of the two eras, adding a few others to those above enumerated:—

Of the Nineteenth Century.	Of All Preceding Ages.
1. Railways.	1. The Use of Fire.
2. Steam-ships.	2. The Mariner's Compass.
3. Electric Telegraphs.	3. The Steam-engine.
4. The Telephone.	4. The Telescope.
5. Lucifer Matches.	5. The Barometer and Thermometer.
6. Gas-illumination.	6. Printing.
7. Electric-lighting.	
8. Photography.	
9. The Phonograph.	
10. Röntgen Rays.	
11. Spectrum-analysis.	

Of the Nineteenth Century.	Of All Preceding Ages.
12. Anæsthetics.	7. Arabic numerals.
13. Antiseptic Surgery.	
14. Conservation of Energy.	8. Alphabetical writing.
15. Molecular theory of Gases.	
16. Velocity of Light directly measured, and Earth's Rotation experimentally shown.	9. Modern Chemistry founded.
	10. Electric science founded.
17. The uses of Dust.	11. Gravitation established
18. Chemistry, definite proportions.	12. Kepler's Laws.
19. Meteors and the Meteoritic Theory.	13. The Differential Calculus.
20. The Glacial Epoch.	
21. The Antiquity of Man.	14. The Circulation of the Blood.
22. Organic Evolution established.	
23. Cell theory and Embryology.	15. Light proved to have finite velocity.
24. Germ theory of disease, and the function of the Leucocytes.	16. The development of Geometry.

2. Of course these numbers are not to be taken as, in any sense, fixed and absolute. Either series may be increased or diminished by taking account of other discoveries as of equal importance, or by striking out some which may be considered as below the grade of an important or epoch-making step in science or civilisation. But the difference between the two lists is so large, that probably no competent judge would bring them to an equality.

3. Again, it is noteworthy that nothing like a regular gradation is perceptible during the last three or four centuries. The eighteenth century, instead of showing

some approximation to the wealth of discovery in our own age, is less remarkable than the seventeenth, having only about half the number of really great advances.

4. It appears, then, that the statement in my first chapter, that to get any adequate comparison with the Nineteenth Century we must take, not any preceding century or group of centuries, but rather the whole preceding epoch of human history, is justified, and more than justified, by the comparative lists now given.

5. And if we take into consideration the change effected in science, in the arts, in all the possibilities of human intercourse, and in the extension of our knowledge, both of our earth and of the whole visible universe, the difference shown by the mere numbers of these advances will have to be considerably increased on account of the marvellous character and vast possibilities of further development of many of our recent discoveries.

6. Both as regards the number and the quality of its onward advances, the age in which we live fully merits the title I have ventured to give it of—THE WONDERFUL CENTURY.

Printed by BALLANTYNE, HANSON & CO.
Edinburgh & London